9102

Fisheries and Oceans

Ministry of Environment

Final Report on

COWICHAN LAKE STORAGE ASSESSMENT

A Joint Federal/Provincial Habitat Development Project

DFO FILE No. 1755-3
KPA FILE No. 2745

FEBRUARY 1991

KPA ENGINEERING LTD.
consulting engineers

Government of Canada
Fisheries and Oceans

and the

Province of British Columbia
Ministry of Environment
Fisheries Branch
Vancouver Island Region

Final Report on

COWICHAN LAKE STORAGE ASSESSMENT

A Joint Federal/Provincial
Habitat Development Project

Your File: 1755-3
Our File: 2745

February, 1991

KPA Engineering Ltd.
300 - 2659 Douglas Street
Victoria, B. C.
V8T 4M3

EXECUTIVE SUMMARY

The objective of this study was to examine the feasibility of acquiring more storage in Cowichan Lake to allow additional flow releases to be made in spring and fall for fisheries management purposes.

To assess the storage requirement, a 58-year period of Cowichan Lake inflows were estimated using recorded Lake level and outflow data. Then a computer simulation model was developed to test the performance of different weir heights in achieving the scheduled releases.

The use of negative storage from Cowichan Lake would not be feasible unless the River through the Village of Lake Cowichan could be dredged to deepen the channel. As this was deemed to have unacceptable impacts for the residents of the Village of Lake Cowichan and on fish habitat, the negative storage option was not pursued further.

As a result of sensitivity analyses with the model, it was found that the release schedule originally proposed in the Terms of Reference should be modified to be:

Period	Flow in m^3/s
April 1 - April 30	21.0
May 1 - June 15	16.5
June 16 - late September	7.0
5-day pulse in late September	21.2
10-day period between pulses	7.0
5-day pulse in early October	21.2 on the first day, reducing in equal steps to 16.0 on the last day
between second pulse and fall floods	9.0

In order to achieve the minimum flow release schedule 19 years out of 20, on average, the controlled storage in Cowichan Lake must be increased by 36 million cubic metres by raising the weir crest by 0.57 m to an elevation of 162.94 m above Geodetic datum.

The effect of such a weir height increase and release schedule would be to increase summer Lake levels by about 0.40 to 0.45 m compared to levels recorded for the 1958 - 1988 period. The new Lake levels would be about 0.2 m higher than the 1990 summer levels. High winter flood Lake levels would not be significantly increased over historical levels for the same discharge.

In general, the effects of the predicted Lake level changes on the shoreline of Cowichan Lake are expected to be relatively minor, because the magnitude of the proposed change is a small fraction of the total natural range of Lake levels. However, during the summer there are six small areas where substantial margins of low elevation land near the shore may be submerged for a longer duration than before 1988 as a result of the proposed changes.

The effects of the proposed weir modifications on Cowichan River flows would be to create a minimum discharge pattern similar to the minimum flow release schedule. Therefore, spring and fall minimum flows would be increased. The summer and winter flows would not be affected, except that the reliability of the summer minimum flow of 7.0 m^3/s would be improved. Riverfront properties would not be affected in any significant way.

The proposed weir modifications and flow changes are expected to have significant benefits for recreation and tourism due to enhanced trout and salmon production, as the opportunities for fresh water angling, native, commercial and sport fishing, and fish viewing are expected to increase. The Lake level changes are not expected to affect occasional visitors and tourists. Some local residents might react adversely to the reduction in some beach areas.

The weir consists of four components: the boat lock, the timber crib structure, the concrete sill and the spill gate structure. All four of these components would need to be modified to raise the weir crest by 0.57 m to an elevation of 162.94 m Geodetic.

The boat lock would require gate height increase, gate strengthening and new electric motors. Also safety instrumentation should be installed to prevent the turbulent rapid filling and draining of the lock under the new high head conditions.

Proposed modifications to the timber crib include raising the crest, plugging the old fishway gaps and enlarging the berm on the downstream side. Because of uncertainty in the life of the wood in the existing crib, the concept proposed herein uses timbers in steel frames to raise the crest, rather than a more permanent and expensive concept. An opportunity for a joint project with Fletcher Challenge Canada to raise the crest and to replace the aging wood may exist. Fletcher Challenge have indicated an intention to test the wood in the crib this summer.

The concrete sill would be raised using cast-in-place concrete with riprap erosion protection on the downstream side, and would allow spaces to include two fry fishways.

At the spill gate structure, the gates would need to be extended, the counterweights, sprocket shaft bearings and electric motor would need to be replaced and the hand crank handles would need to be lengthened. The main fishway would require two new baffles and two new sections of fry fishway.

The total estimated construction cost, in 1991 dollars, is $246,200. With the engineering and construction supervision costs added the total project cost would be $311,700.

Government of Canada
Fisheries and Oceans
and the
Province of British Columbia
Ministry of Environment
Fisheries Branch
Vancouver Island Region

Final Report on

COWICHAN LAKE STORAGE ASSESSMENT

A Joint Federal/Provincial
Habitat Development Project

Table of Contents

		Page
EXECUTIVE SUMMARY		
1.0	INTRODUCTION	1
	1.1 Background	1
	1.2 Scope	3
2.0	ESTIMATION OF ADDITIONAL STORAGE REQUIREMENT	5
	2.1 Criteria and Constraints	5
	2.2 Cowichan Lake Inflow Estimation	7
	2.3 Feasibility of Using Negative Storage	10
	2.4 Water Balance Model	12
	2.5 Computed Storage Requirement and Weir Height Increase	17
3.0	IMPACTS OF INCREASING LAKE STORAGE	22
	3.1 Cowichan Lake Levels	22
	3.2 Lakeshore Properties	24
	3.3 Cowichan River Flows	26
	3.4 Weir Operation	28
	3.5 Recreation and Tourism	30
4.0	DESIGN CONCEPTS AND CONSTRUCTION COST ESTIMATES	33
	4.1 Design Procedure	33
	4.2 Boat Lock	34
	4.3 Timber Crib	36
	4.4 Concrete Sill	40
	4.5 Spill Gates	41
	4.6 Project Cost Estimates	44
5.0	RECOMMENDATIONS	46

Table of Contents - Continued

Page

TABLES

Table 1 - Original Minimum Flow Release Schedule 5
Table 2 - Summary of Sensitivity Test Results 18
Table 3 - Expected Average Lake Level Increases 22
Table 4 - Summary of Total Project Cost Estimates 44
Table 5 - Recommended Minimum Flow Release Schedule 46

FIGURES

Figure 1 - Cowichan River Drainage Area
Figure 2 - Stage-Discharge Curves at Lake Outlet
Figure 3 - Schematic Water Surface Profiles Through Weirs
Figure 4 - Water Balance Model Output for a Low-Flow Year
Figure 5 - Additional Weir Height vs. Ability to Achieve Scheduled Releases
Figure 6 - Historical Lake Level Summary and Assumed Rule Curve
Figure 7 - Map of Cowichan Lake
Figure 8 - Historical Lake Outflow Summary
Figure 9 - Cowichan Lake Weir Modifications, General Arrangement
Figure 10 - Cowichan Lake Weir Modifications, Boat Lock Structure
Figure 11 - Cowichan Lake Weir Modifications, Timber Crib and Concrete Sill
Figure 12 - Cowichan Lake Weir Modifications, Spill Gate Structure

APPENDICES

Appendix 1 - Cowichan River Flow Releases and Fish Migration
Appendix 2 - Statement of Work
Appendix 3 - Samples of Output from the Computer Model
Appendix 4 - Construction Cost Estimates

Government of Canada
Fisheries and Oceans

and the

Province of British Columbia
Ministry of Environment
Fisheries Branch
Vancouver Island Region

Final Report on

COWICHAN LAKE STORAGE ASSESSMENT

A Joint Federal/Provincial
Habitat Development Project

1.0 INTRODUCTION

1.1 Background

Location

Cowichan Lake, located centrally near the south end of Vancouver Island, is one of the larger lakes on the Island with a surface area of 63 km^2. It is the source of the Cowichan River, which winds about 47 km from the Lake to tidewater at Cowichan Bay. The City of Duncan and the Village of Lake Cowichan are located along the River. Figure 1 shows the Cowichan River drainage basin, the Lake and the communities in the basin.

History

Because of its size, the Lake offers the potential to effect significant changes in River flows with relatively small changes in Lake level. This feature prompted British Columbia Forest Products Ltd. (now Fletcher Challenge Canada) to build a weir in 1957 at the outlet of the Lake with the objective of increasing Cowichan River flows during the summer low flow period to ensure an adequate water supply for their pulp mill in Crofton.

The original weir comprised a boat lock and a timber crib structure with vertical slots designed to act as fishways. This weir controlled storage within a range of Lake levels of about 0.6 m. Flashboards allowed the operators to surcharge the Lake level by an additional 0.3 m. It appears that the flow regulation in this early stage of the weir development was achieved by use of the boat lock gates.

In 1965 the weir was upgraded by the addition of a set of four spill gates to improve control of the Lake discharges. The flashboards were replaced by precast concrete units, which permanently increased the operating range of Lake levels controlled by the weir to approximately 1.0 m.

Fisheries Interests

During the past decade, the Department of Fisheries and Oceans (DFO) have become concerned over the decline of chinook salmon stocks spawning in the Cowichan River. With the cooperation of the British Columbia Ministry of Environment (BCMoE), the DFO tested a fall flow release strategy in 1988 and 1990 to assist chinook migration to the spawning grounds. The new flow release pattern involved retaining water so that the Lake was held to full storage until early July. The additional stored water was released in two 5-day pulses in late September and early October. Data from the fish counting fence on the lower Cowichan River showed a dramatic correlation between the onset of these pulsed flow releases and chinook migration (see Appendix 1).

In DFO's assessment the additional flow not only triggered the start of the upstream migration, but also allowed the fish to reach the spawning grounds more quickly, in better condition and with less exposure to predation. As a result, the escapement of the returning adult chinook was significantly increased in 1988 and 1990.

The Cowichan River also supports a high-quality rainbow, steelhead, cutthroat and brown trout sports fishery of 12,000 angler-days

annually. Persons with a stake in this fishery expressed concern that reducing flows by starting control too early in the spring decreases sports fishing opportunities and dewaters the redds.

It was recognized that flow releases patterned after the experiment could only be provided during years with above-average runoff during late spring or summer months. Therefore, in view of the positive outcome of the flow release experiment and the need for maintaining sufficient spring and summer flows for rearing salmonids, the DFO and the BCMoE retained KPA Engineering Ltd. in August 1990 to undertake an assessment of the storage required to achieve fall flow releases for the migrating chinook while maintaining adequate flows for the trout fishery in the spring and for other established users during the summer. The findings of the assessment are documented in this report.

1.2 Scope

The overall objective of this study was to examine the feasibility of acquiring more storage in Cowichan Lake. The Terms of Reference for this assignment appear in the Statement of Work issued by the Federal/Provincial Steering Committee established for this project (see Appendix 2) and the KPA proposal for this study submitted in August 1990 (KPA File No. P10.166).

The scope of this study contained the following components:

1. determination of the volume of storage required in Cowichan Lake to meet the minimum flow release schedule. (During the course of the study, the flow release schedule was modified slightly from that defined in the Statement of Work.)

2. investigation of the feasibility of storing the required volume of water above the current full-storage elevation (FSE) of 162.37 m Geodetic by increasing the height of the weir. (This is referred to as positive storage.)

3. investigation of the feasibility of providing the required storage or part of it by drawing water from below the zero storage elevation (ZSE) of 161.40 m Geodetic. (This is referred to as negative storage.)

4. development of concepts to achieve the required volume through positive storage, negative storage or a combination of the two.

5. determination of the impacts of the most feasible concepts on weir operation, private lands, recreation and tourism.

6. preliminary design of the most feasible concepts and estimation of costs to modify the weir.

7. preparation of a report to present the findings of the above.

8. preparation of three presentation figures suitable for display at a public meeting.

Three items related to this project but which were considered to be outside the scope are:

1. design of any improvements to the weir that are not a result of new loadings brought about by any proposed modifications to the weir

2. design of fishways, although KPA's plans for any weir modifications should accommodate the DFO fishway designs, and fishway costs are to be included in the total project cost estimates.

3. details of mitigation measures for affected properties around the Lake and its tributaries.

2.0 ESTIMATION OF ADDITIONAL STORAGE REQUIREMENT

2.1 Criteria and Constraints

Release Schedule

The amount of storage required in Cowichan Lake depends on the timing and magnitude of the natural inflows and the minimum flow release schedule. The schedule which is presented in the Statement of Work and was initially investigated appears below:

Table 1
Original Minimum Flow Release Schedule

Period	Flow in m^3/s
April 1 - April 30	21.0
May 1 - June 15	16.5
June 16 - late September	7.0
5-day pulse in late September	21.2
10-day period between pulses	7.0
5-day pulse in early October	21.2
Between second pulse and fall floods	7.0

During the course of the study it was mutually agreed to alter the schedule such that only the first day of the second 5-day pulse was required to be 21.2 m^3/s or more. The minimum flow on the following four days would be either 21.2 m^3/s or whatever the weir could pass with all gates wide open, whichever is less.

For this study it was assumed that the first pulse would occur during the period September 22 - 26, and the second pulse during October 7 - 11 inclusive.

Reliability Criterion

Because the quantity and timing of natural inflows vary from year to year, the necessary amount of storage also depends on how often the

system is allowed to fail to meet the required releases. The Steering Committee has selected a 95% reliability criterion. In other words, it was considered tolerable to allow the system to fail to achieve the specified releases in 1 year out of 20, on average.

Objectives of the Release Flows

The aims of the proposed minimum flow release schedule were to:

1. maintain or enhance spawning and rearing flows for all salmonids

2. provide an adequate flow during the spring for the trout and steelhead fishery interests

3. maintain the same minimum flow through the summer as is currently released to satisfy existing domestic, industrial and other licensed uses

4. provide the two fall releases to assist chinook migration.

Downstream Users

At present, several downstream users rely upon the minimum summer period flow of 7.0 m^3/s. The major user of the water during the summer period is Fletcher Challenge Canada, which withdraws 3.11 m^3/s from the River for their pulp mill in Crofton. The City of Duncan depends on the minimum flows in the River to ensure adequate dilution of the effluent from their sewage treatment plant. These flows are also required to maintain acceptable temperatures in the River for salmon fry and trout.

Lakeshore Properties

In addition to the downstream users, the Lake supports a heavy recreational use, especially during the summer months. Many homes and cottages line the shore along several parts of the Lake. These existing

lakeshore residents and recreational users may be adversely affected by large increases or decreases in the level of Cowichan Lake, therefore their interests also represent a constraint to the extent of water level change that has been considered in this study.

2.2 Cowichan Lake Inflow Estimation

Data Sources

To determine lake inflows, both outflow and lake level data are required. The major source of the flow and level data used in this study was Water Survey of Canada, which has been operating a streamflow gauge on Cowichan River near the outlet of the Lake and a water level gauge in the Lake itself for many years. KPA obtained the data for the entire period of record for both stations in digital form.

The streamflow gauge, named Cowichan River at Lake Cowichan (WSC Station No. 08HA002), is currently located on the downstream side of the highway bridge in the Village of Lake Cowichan. The gauge was established in March 1913, and was read manually until October 1919, at which time continuous records ended and were followed by two years of miscellaneous readings until the gauge operation was discontinued in 1921. The gauge was re-established with a continuous recorder in September 1940 and, with the exception of some periods for which flows have been estimated by WSC, it has been operating continuously since then. In general, this flow data appears to be of good quality, especially since 1940.

The Lake gauge, named Cowichan Lake near Lake Cowichan (WSC Station No. 08HA009), was originally located near the weir, but was moved 1.3 km westward along the north shore in February 1983. The first Lake gauge was established in March 1913, and was operated manually until it was discontinued in October 1921. The Lake gauge was reestablished in December 1952, but was read only three times a week until April 1971. Since then it has been read on a daily basis, with

a few minor gaps in 1973 and in 1982. This gauge has always been a manual gauge, therefore its data is based on spot readings taken twice a day, once a day or three times per week.

In summary, the raw data is of varying quality, has some common overlapping periods of record and much of it, especially the Lake level data in the 1950s and 1960s, is riddled with small gaps.

Data Treatment to Fill Gaps

In order to produce a reliable estimate of the 20-year return period, low Lake level condition, it was important to obtain as many years of inflow data as possible. Therefore, it was necessary to establish as many years of continuous daily outflow and Lake level data as possible.

The first step in preparing the data for inflow estimation was filling the small gaps. All gaps of two days or less were filled by linear interpolation using the measured data adjacent to each gap. This was accomplished with the aid of a computer spreadsheet.

The longer gaps, and long periods where one gauge was operating and the other was not, were estimated by developing a stage-discharge relationship between the Lake level and the River discharge which was the same as the Lake outflow. Thus, where Lake level data was available, but River discharges were not, the River discharges were estimated from the rating curve. This was also done in reverse, estimating Lake levels using the River flows. This approach was valid because, fortunately, these major gaps existed for periods before the weir was built or when the weir was not regulating the flow.

The stage-discharge curve was developed by plotting all recorded River discharges against the Lake level measured on the same day for

generally consistent conditions. For example, the period since the weir was modified (1966 - 1990) represents one generally consistent stage-discharge condition.

The four rating curves used to fill the data gaps are shown in Figure 2. The two curves for the post-weir periods were drawn through the concentrated band of points representing the situations where the weir gates were fully open (lower Lake levels and higher flows).

After applying the above methods, a total of 57 years and 10 months of concurrent daily Lake level and outflow data was prepared. The data fell into two consecutive blocks. The first block spanned the period from March 1913 to October 1921, and the second, from September 1940 to December 1989. The two blocks were merged on a day in September when the Lake levels were the same in both 1921 and in 1940.

Calculation of Inflows

Inflows to Cowichan Lake were estimated for this 58-year set of data by back-routing the flows through the Lake using the storage equation:

$$\text{Inflow} = \text{Outflow} + \frac{\text{Change in Storage}}{\text{Time Interval}}$$

where the Inflow and Outflow are averages over the time interval.

Since only daily level and outflow data was available, a time interval of one day was used. The inflows calculated by this method showed a high degree of day-to-day irregularity which appeared to be randomly distributed about the mean. Upon investigation it was determined that the irregularities were caused by "noise" in the Lake level data. Because Cowichan Lake is so large, small differences in Lake level translate to large differences in calculated inflows. The most

likely cause of the data "noise" appears to be wind setup and seiches, because the Lake is prone to frequent strong and sustained winds along its length, and the gauge is located near one end of the Lake. When the inflows were very low, the irregularities gave rise to frequent negative numbers of small magnitude in the inflow data. These appeared to be mostly due to the data "noise", although it is possible on some occasions during low inflow periods and warm temperatures for the Lake evaporation to exceed the inflow, resulting in apparent "negative inflows".

The Lake level data "noise" affected only short term (i.e. less than five days) estimates of inflow and appeared to be distributed about the mean. Therefore, it was considered valid for use in the assessment of long term (i.e. several months) storage requirements. However, to reduce the degree of irregularity and to more accurately coordinate the time intervals for the inflow, outflow and change in storage parameters, two-day moving averages of the Lake level data were used in the inflow calculations.

The inflow data estimation was accomplished by programming a computer spreadsheet to perform the calculations. An example of one year's estimated inflow data appears in one of the graphs shown in Figure 4.

2.3 Feasibility of Using Negative Storage

The possibility of drawing water from below Cowichan Lake's existing Zero Storage Elevation (ZSE) of 161.40 m Geodetic was investigated. The first step was to determine the available head across the weir when the Lake is at the ZSE and the summer baseflow of 7.0 m^3/s is discharged from the Lake. This was accomplished by conducting a level survey from the WSC River gauge to the weir to determine the average River slope at a relatively low flow. Using this slope, the stage-discharge information for the low flows at the River gauge was projected upstream to the downstream side of the weir. Figure 3 shows schematic profiles from the Lake to the river gauge under three different discharge conditions, including the situation described above.

It was estimated that at the 7.0 m^3/s flow, the head difference across the weir was only .042 m. This represents only four days of flow at 7.0 m^3/s, assuming the weir could be modified to release this flow with almost no head loss through the weir. To reduce the head loss, the openings in the weir would have to be enlarged. Since the spill gates would already be open wide at this stage, the only remaining options would be to open the boat lock gates or construct large new gates elsewhere in the weir.

Neither of these options are attractive. The cost of new gates would certainly not be worth the very small additional flow that could be delivered with .042 m of head. Using the boat lock gates to achieve the minimum flows for a few days after the Lake level has dropped below the ZSE may be feasible, but the issue of safety for boaters approaching the lock may be a concern. Because neither of these approaches offers a substantial amount of accessible storage, they were not pursued.

One way of increasing the head difference across the weir would be to lower the elevation of the water on the downstream side of the weir. It would require dredging the River bed over most of a 2 km reach downstream from the weir to lower the tailwater enough to allow gravity drainage of a substantial volume of Lake water below the ZSE. Such dredging was considered unacceptable by the DFO and the Fish and Wildlife Branch of the BCMoE because of the potential harm that dredging would cause to fish habitat. It would also result in lowered river levels through the Village of Lake Cowichan, affecting existing docks and boat ramps in this area.

Another way of accessing the negative storage in the Lake would be to pump the water from the Lake into the River. This concept would entail construction of a pumpstation and the installation of very large, low-head pumps to deliver flows in the order of 21.2 m^3/s. The overall system, including the pumps and the power feeding them, would have to be designed and built to a very reliable standard in

order to avoid the possibility of a system failure when the Lake was drawn down. The consequences of such a failure could be the temporary cessation of all flow in the upper part of the Cowichan River. Because of the high cost of such a pumping system, and the apparently more economic possibilities offered by positive storage options, this concept was abandoned.

A syphon would not be feasible because it would require a very long, large-diameter pipeline. It would also result in the complete dewatering of the Cowichan River through the Village of Lake Cowichan.

As no promising concepts using negative storage to deliver at least a significant portion of the required release flows were identified, the negative storage option was not pursued further.

2.4 Water Balance Model

Model Description

To estimate the storage requirement, it was necessary to develop a tool that would simulate the operation of the weir, using all 58 years of calculated inflow data, and compute outflows and Lake levels for a variety of weir heights and release flow schedules. KPA wrote a computer program, called the Cowichan Lake Water Balance Model, to perform this simulation. The program was written in Turbo Pascal, and was designed specifically for Cowichan Lake, although it could be modified to simulate other reservoirs or lakes. The program, which is menu-driven, can be run on any IBM compatible microcomputer with a minimum of 512 Kb of RAM and a hard disk. For faster execution, an 80386 processor and a math coprocessor are recommended, but not necessary.

In the Model, the weir height is represented by the Lake's Full Storage Elevation (FSE), which is variable. The elevation datum used in the program is the Cowichan Lake gauge datum, which corresponds to

160.944 m above Geodetic datum. The minimum flow release schedule is also variable in the Model. With these two variables, the user can test the effects of different weir heights and controlled releases on outflow and Lake level.

The decision logic of the program is briefly outlined as follows:

1. With the inflow, outflow and Lake level known for a given day the program reads the next day's inflow.

2. If the simulation was in the "off control" mode the previous day, the program checks to see whether control should start. Control is started when the first date in the release schedule is passed (typically April 1), and when the Lake level is below the FSE.

3. Once "on control", the program remains in this mode until the end of the season.

4. During the "on control" mode the program discharges the minimum release flow. If the minimum release flow cannot be achieved because of low Lake levels, then the flow that would occur if all spill gates were opened is released.

5. If the Lake level exceeds the FSE during the control period because of high inflows, the program increments the releases by 9 m^3/s per day until the Lake level drops below the FSE. At this point, the program starts decrementing the release flow by 9 m^3/s per day until it meets the scheduled release flow, or until the Lake level rises above the FSE and the above procedure is repeated. This often causes a characteristic 9 m^3/s oscillation in the simulated outflow hydrograph.

6. The program switches to the "off control" mode when the Lake level exceeds the FSE for the first time after passing a "first date to stop control", which is usually specified by the user to be in October.

The Model provides the following types of output:

1. a tabular summary for an entire run, listing among other things, the number of years in which the weir operation could not achieve the specified minimum flows

2. a tabular summary of daily inflow, outflow and Lake level data for any year in a run

3. graphical representations of the inflow, outflow and Lake level for any year in a run.

Sample tabular and graphical outputs from the model appear in Appendix 3 of this report. Figure 4 shows some graphical output produced by the model for the year 1985. This figure was prepared by a CAD program which read the output data file produced by the Cowichan Model.

Weir Operation

The Cowichan Lake Weir is only operated during the spring, summer and early fall. Operation typically begins near mid-April, with the exact date depending on the water level of the Lake. When the falling Lake level approaches the Full Storage Elevation, the operator closes the boat lock gates and begins to lift the spill gates in stages, restricting the outflow from the Lake to maintain the level near the FSE at the beginning of the control period. Throughout the spring, summer and early fall the operator then strives to match the Lake level with the levels set out in the rule curve while complying with the minimum flow releases stated in the water licence.

The rule curve is a graph of target Lake levels versus time which spans the operating period. If the Lake levels are tracking the rule curve closely, excess inflows are passed as soon as they begin to

raise the Lake level. If the Lake level falls below the rule curve, such additional inflows are retained to lift the Lake level to the rule curve values.

The water licence also defines limits for the maximum allowable rate of increase and decrease in outflows under normal circumstances. Although these constraints are sometimes waived in reality, the model attempts to simulate them in a simplistic manner. The model restricts the rate of increase or decrease of outflow during the control period to a maximum of 9 m^3/s per day, which corresponds to a rate of change of one foot of river level at the gauge per day when the flow is near 15 m^3/s.

Weir operation continues until the fall rains raise the Lake above the FSE. This typically occurs in October. At this time, the operator opens all the spill gates, both boat lock gates, prepares the site for winter and leaves the place unattended until next spring.

Model Simulation of Weir Operation

The Model does not exactly simulate weir operation as it would be carried out in reality, because, in fact, the weir will be operated according to the rule curve established by the BCMoE. However, before a rule curve can be defined, the amount of storage required, the weir height and the release schedule must be confirmed. It is only this first step that the Model is designed to achieve.

The Model simulates a hypothetical weir operation where as much water as possible is stored during the control period. In the Model, excess water is spilled only when the Lake exceeds the FSE. As a result, for years with high spring and summer inflow, the Model maintains a higher than necessary water level, which in reality would be spilled much sooner. The approach used by the Model ensures that the only cause for failing to meet the flow release schedule would be inadequate inflows.

Application of the Model to the Storage Estimation Problem

The Model was applied by simulating this hypothetical operation using the 58-year set of inflow data for a specified FSE and minimum flow release schedule. In its output, the program listed the number of years for which the minimum flow release schedule could not be achieved. The Model was then run again several times for different values of the FSE. The "number of years failing" was plotted against the FSE values, and a curve was drawn through the points. A line representing the 1 in 20-year probability of failure was drawn on the graph, and the point of intersection of this line with the curve indicated the FSE, and therefore the storage, required for the specified release schedule. Examples of such plots are shown in Figure 5.

Removal of 1944 Outlier Data

Although almost 58 years of Lake inflow data was available, only 56 years were used to determine the 20-year return period for failure. The 1913 data was not used because it was only 10 months long and, being the first year in the run, it was affected by the assumptions made to initialize the program calculations.

The results from another year, 1944, were also not used because the inflows were so low that it was considered unreasonable to include this year's results in the analysis. To check for possible data error, other streamflow records for Vancouver Island rivers were examined. While all showed less than average flows during the spring and summer of 1944, none showed such a low ratio to the mean as the Cowichan River did. A frequency analysis conducted for all the April to September mean flows recorded for the Cowichan River data showed the 1944 April to September flow volume had a return period in excess of 300 years. Therefore it was considered unreasonable to retain this outlier in a set of only 58 years of data.

2.5 Computed Storage Requirement and Weir Height Increase

Existing and Proposed Release Schedules

In the past, the release schedule for Cowichan Lake outflows was a constant 7.0 m^3/s throughout the entire control period. It is proposed that the release schedule be altered to that described in the Statement of Work, with increased spring flows for the trout fishery, and two pulses of flow in the early fall period to aid chinook migration. The proposed release schedule was entered into the Model and, as described in the previous section, the Model was run for a range of FSE values.

The results from this set of runs were plotted and appear as the upper curve in Figure 5. The graph indicates that the existing weir would have to be raised by 0.66 m to provide these release flows with a 95% reliability.

Sensitivity Runs

After these preliminary findings were established, the Model was used to test the sensitivity of various changes to the release schedule originally proposed in the Statement of Work. Table 2 summarizes the changes tested and the effect of these changes on the required weir height increase.

These sensitivity test results indicated where changes could be made in the release schedule to have the maximum effect in reducing the required weir height increase. The results from Test No. 11 and 12 are shown as the two lower curves in Figure 5.

Effect of Changes to Spring Releases

It is obvious that reductions in the spring releases have a negligible effect on the need for more storage. This is due to the fact that typical springtime inflow volumes in a dry year are similar to the

Table 2

Summary of Sensitivity Test Results

Test No.	Change to Release Schedule	Indicated Effect on Weir Height Increase of 0.66 m
1.	Reduce April releases by 10%	almost no change
2.	Reduce May 1 - June 15 releases by 10%	slight reduction
3.	Change the May 1 date for reducing the spring releases to April 26	no change
4.	Change the June 15 date for ending the spring releases to June 10	slight reduction
5.	Increase the spring releases to 34 m^3/s for April 1 - June 30	huge additional increase (more than 2 m)
6.	Reduce the last fall fish release by 8%	moderate reduction
7.	Reduce both fall fish release pulses by 8%	moderate reduction (slight change compared to Test No. 6)
8.	Reduce summer baseflow by 10% (from 7.0 to 6.37 m^3/s)	moderate reduction (0.11 m lower)
9.	Increase summer baseflow by 10% (from 7.0 to 7.79 m^3/s)	large additional increase (0.18 m higher)
10.	Increase summer baseflow by 7% (from 7.0 to 7.5 m^3/s)	moderate additional increase (0.10 m higher)
11.	Reduce second fall fish release by requiring only the first day of the second pulse to be 21.2 m^3/s	moderate reduction (0.09 m lower)
12.	Reduce both fall fish releases by requiring only the first day of the first pulse to be 21.2 m^3/s	large reduction (0.19 m lower)

scheduled release volumes. Therefore, they do not require a large amount of storage. The effect of the proposed release schedule on the spring flows will primarily be to increase the minimum discharges by reducing the peaks and truncating the troughs of a natural outflow hydrograph.

There was no merit in reducing the spring releases or changing their durations in the proposed schedule. On the other hand, a large increase in the spring releases would require a very large increase in the height of the weir. Test No. 5 investigated a suggestion that the spring flows be increased to 34 m^3/s (1200 cfs). This would clearly involve a very large cost and would create unacceptably high Lake levels for lakeshore property owners.

Effect of Changes to Summer Releases

If the summer baseflow, which is currently maintained at 7.0 m^3/s (247 cfs), would be reduced to 6.37 m^3/s (225 cfs) in the proposed release schedule, the existing weir would require raising by 0.55 m, instead of 0.66 m. Such a reduction, however, would decrease the minimum flows that the users downstream of the weir have become accustomed to. The percentage decrease in these baseflows would be magnified downstream of the 3.11 m^3/s withdrawal by Fletcher Challenge Canada for the Crofton Pulp Mill. These baseflows may be relied upon to provide dilution of effluents and temperature control for fish. Therefore, no reduction in the 7.0 m^3/s summer flow is proposed.

If the summer baseflow were to be increased to 7.79 m^3/s, then the existing weir would have to be raised by 0.84 m. For a release flow increase to 7.5 m^3/s (265 cfs) model runs indicate the weir would have to be raised by 0.76 m. Either of these weir heights may represent a considerable incremental construction cost, and would further

increase Lake levels. As there is no agency at present which is requesting that this baseflow be increased, this possibility was not pursued further, and no increase to the 7.0 m^3/s summer flow is proposed.

Effect of Changes to Fall Releases

The sensitivity tests clearly showed that a relatively small decrease to the latter part of the fall fish releases had a significant effect on the required weir height. This is due to the fact that a reduction in this part of the release schedule not only reduces the Lake storage volume requirement, but also reduces the minimum Lake level, since the Lake does not need to be as high to deliver the lower discharge on the last days of the last fish release. The second factor has a greater effect on the weir height.

On the basis of this observation, refinements to the fall fish releases were tested with the objective of minimizing the weir height increase while maintaining the maximum benefit of these pulses. This was achieved by reducing the minimum release for the latter days of the fish pulses to mimic natural recession flow from the Lake with all spill gates wide open. These refinements were simulated in Test No. 11 and 12, and appear graphically in Figure 5. The DFO indicated that, in their estimation, the fall releases proposed in Test No. 12 were too low, but the releases in Test No. 11 were adequate.

Recommendation of Release Schedule and Weir Height Increase

In accordance with the findings of the sensitivity tests, we recommend that the changes to the release schedule proposed in Test No. 11 be adopted, and that the existing weir be raised vertically by 0.57 m.

The revised release schedule calls for a minimum flow of 21.2 m^3/s (750 cfs) on only the first day of the second pulse. Assuming the Lake level is right on the rule curve on this day, then the weir should just be able to pass 21.2 m^3/s with all spill gates wide open. If the gates were to remain wide open for the next four days, then, depending on inflows and assuming no rainstorm runoff occurs during this period, the flow on the last day of the second pulse would typically be near 17.9 m^3/s, but in a very low inflow year it could fall as low as 16.5 m^3/s.

It was originally intended that, following the second fall fish release pulse, the 7.0 m^3/s baseflow would be resumed until the fall rainstorm runoff would refill the Lake above the FSE. However, it is evident that there would be excess water available after the second pulse that may be more beneficial released than retained. It was estimated that a continuous baseflow of 9.0 m^3/s (318 cfs) could be released after the second pulse, and that this flow could be achieved as a minimum for at least 19 years out of 20, on average. Therefore, we also recommend this further revision be made to the release schedule.

3.0 IMPACTS OF INCREASING LAKE STORAGE

3.1 Cowichan Lake Levels

Spring, Summer and Early Fall

The construction of the Cowichan Lake weir in 1957 altered the pattern of Lake levels from April to October of every year. After the weir was built, the Lake level was generally higher during these seasons than it was before. The magnitude of the difference is shown in Figure 6, which traces separate historical Lake level ranges for the pre-weir and post-weir periods. The curves which represent the average Lake levels give the best representation of long-term differences. They show that the presence of the weir resulted in a Lake level increase of about 0.5 m in July and August, and lesser differences in May, June and September.

The proposed weir will result in another increase in Lake levels. An estimate of this increase is also shown on Figure 6. It is expected that the average Lake levels will follow a curve similar to the one labelled "assumed rule curve" in Figure 6. This indicates that the Lake levels would be increased by the following amounts in this period:

Table 3

Expected Average Lake Level Increases

Month	Increase (m)
April	0.40
May	0.50
June	0.45
July	0.40
August	0.40
September	0.30

Another comparison which may be more meaningful to those with recent experience with Lake levels is the difference between the "assumed rule curve" and the actual recorded lake levels for 1990, which is also shown in Figure 6. This comparison shows that, from mid-June to October, the proposed levels would be approximately 0.2 m higher than they were in 1990. After the proposed weir modifications, the Lake level would be the same in mid-August as it was in mid-July in 1990. These levels are both the same as the 1958 - 1988 average level at the beginning of June.

Estimation of the Assumed Rule Curve

In order to estimate the expected changes of the Lake level through the control period, it was necessary to anticipate an approximate rule curve. This was achieved using the Model by selecting three years of inflow data which had no significant runoff events during the late spring and summer seasons. The years 1943, 1973 and 1985 were used. The Model was applied to the problem by varying the FSE to find the recession curve that just satisfied the flow release schedule, with no excess water to spare. The critical day in these simulations was the first day of the second pulse of fall fish flows, because if there was a slightly insufficient amount of storage, then this was the first day that the minimum releases could not be achieved.

After finding the FSE which created the desired recession curve, the lake level curves from these three simulations were superimposed on one another. The three curves showed close agreement through July, August and September, but diverged for the earlier periods according to the inflows received during the late spring period. The "assumed rule curve" was sketched by taking an average position through the three curves for the June to October period, then projecting a smooth curve back through May and April to match the proposed FSE on April 1.

Late Fall and Winter

For the remainder of the year, Lake levels were essentially unaffected by the weir for two reasons. First the weir was not operated during the winter, so all spill gates and the boat lock were open, and secondly, the presence of the fixed part of the weir did not increase high Lake levels because the hydraulic control of the Lake outlet shifted downstream at high flows. Therefore, at high flood levels, the weir no longer controlled the Lake levels. This can be seen in Photo 12, which shows an insignificant head loss for flood flow of 195 m^3/s passing over the submerged weir on 27 November, 1990. Lake levels at lower discharges, however, are expected to be increased by a greater amount as a result of the presence of the proposed weir.

3.2 Lakeshore Properties

The effects of the predicted Lake level changes (described in Section 3.1) on the shoreline of Cowichan Lake are expected to be relatively minor, because the magnitude of the proposed change is a small fraction of the total natural range of Lake levels. The maximum anticipated change of 0.5 m represents 12% of the total historic range of recorded Lake levels of 4.32 m, and 37% of the range of average Lake levels (1.36 m) since the weir began operation in 1957. It is expected that the range of Lake levels would decrease after the proposed weir modifications because the minimum levels would not be as low, but the peak levels would be essentially the same as they are now.

Perhaps the greatest perceived effect on lakeshore properties would be the fact that Lake levels would be about 0.45 m (18 in.) higher than they typically have been between 1958 and 1988 on the same date throughout the summer period. This perception would be magnified by the fact that this is the period of greatest recreational use of the lakeshore by residents, cottage owners, campers and visitors.

Properties with average to steeply sloping shores will likely see little effect to the area of their lakefront, whether it is a gravelly beach or grassed lawn. However, those properties with a very low slope shore area located in the zone of the proposed water level changes will be most affected.

KPA conducted two inspections of the developed parts of the Cowichan Lake shoreline by boat. One of these was at a low Lake level on September 25, and the other was at a flood level on November 27. At the time of the earlier inspection, it was not known what the proposed Lake level increases would be, therefore a detailed assessment of how much shore area would be underwater at a given time of the summer season was not possible. However, it was possible to identify five shore areas where the potential for significant areal extent of inundation existed.

These areas are identified on the map in Figure 7 as areas of "low elevation land". Three of the areas are developed with residences or summer cottages. One of the areas contains a Recreational Vehicle Park in Honeymoon Bay. Another area is farmland at the mouth of Robertson Creek.

Some of the photographs taken during the field inspections are presented after the Figures Section of this report. The locations are described under each photo. Photos 1 to 6 show some of the low elevation lands near residences. Photo 9 shows the Recreational Vehicle Park.

The area at the mouth of Robertson Creek which is not vegetated with brush is pasture (see Photos 7 and 8). The ground water regime adjacent to the Lake is expected to change in step with the Lake level changes. As the land elevation rises away from the Lake, the change in ground water table will rapidly diminish. Thus, the farmland could be affected not only by inundation later into the growing season, but by an elevated ground water table as well.

A sixth area identified in Figure 7, shown in Photo 10, locates three docks made of rockfill which have a top elevation near the proposed FSE. These docks may have to be raised to be useful in the early summer season.

To mitigate the impacts of higher water levels on the lands near residences, fill could be placed to raise land subject to inundation to an elevation which would be similar, relative to the water, as it was before 1988. This would involve placing thicknesses of fill up to 0.45 m and would steepen the slopes of the beach at the edge of the fill nearest the Lake.

Prior to any commitment to mitigation the extent of inundation at each of these areas should be more accurately assessed. Therefore, we recommend that these six areas be surveyed to determine how much shore area would be underwater on certain dates in the late spring and summer period in a typical year before any final decisions on mitigation measures be made. A less rigourous alternative to a survey would be observation and photography of these areas at relevant Lake levels.

3.3 Cowichan River Flows

As the weir altered Lake levels, so did it affect the River discharges. The weir was built with the intention to allow increased summer minimum flows, and it successfully accomplished that function. Similar to the effect on Lake level range, flow control at the weir reduced the natural range of River levels by increasing the minimums. The intention of the proposed weir modifications is to increase spring and fall flows.

Historical Patterns

Figure 8 shows the historical River discharge ranges for periods before and after the weir was built. The maximum, average and minimum flows are shown for each day during each of these two periods. The

curves which represent the average discharges give the best representation of long term differences. They indicate that the presence of the weir resulted in a reduction of average and minimum River discharges from mid-April to mid-June, but an increase in average flows and a larger increase in the minimum discharges from July to October.

Effect of Proposed Weir

The proposed weir modifications will result in minimum discharges similar to the minimum flow release schedule. This schedule is superimposed on the historical flow summary presented in Figure 8, indicating when and by how much the minimum flows would change. The average discharges would be expected to increase in the mid-May to mid-June period, and during late September and early October. The average flows would decrease from late March to mid-May, the period during which it may be necessary to raise the Lake level to the FSE.

From June 15 until late September the flows in the Cowichan River would be essentially the same before and after weir modifications, because there is no change proposed to the minimum release flow of 7.0 m^3/s during this period.

It should be recognized by all those who have a stake in the Cowichan River flows during the summer period that in the very low inflow years the first casualty in the proposed minimum flow release schedule would be the second fall pulse for chinook migration. The next casualty would be the first fall pulse. In other words, when there is not enough water, the fall fish releases will be reduced, and other flow releases would not be affected. Inadvertently, the proposed weir modifications and planned release schedule will improve the factor of safety for achieving the minimum 7.0 m^3/s flow throughout the summer and early fall. This is a hidden but important benefit to all users who depend on these minimum discharges for dilution of effluents, temperature control, depths of water for navigation and reliability of water supply.

Riverfront Properties

The residents along the Cowichan River, and others who use the River, will probably notice little change to the pattern of river water levels and flows for most of the year. Winter and summer flows would be essentially unchanged by the weir modifications. Spring flows in dry years, and low flow periods between runoff events in the spring will be boosted by releases from the weir but, because these would not be unusual, they would likely not attract any attention.

It is more likely that the fall fish releases would be noticed by residents along the river, especially if there is no rain during or preceding the releases. Although the proposed release flows are not large (21.2 m^3/s), they may be unexpected, therefore persons living near or using the River should be warned about the releases in advance.

It is clear that there would be no significant negative impacts to properties adjacent to the Cowichan River from the proposed weir modifications and release schedule, because the anticipated Cowichan River flow changes lie well within the River's normal range of flows.

3.4 Weir Operation

Discussion relating to the specific operation of the boat lock gates and the spill gates are found in Section 4.2 and Section 4.5 respectively.

Weir Operators

The weir is presently staffed by personnel hired by Fletcher Challenge to carry out the following tasks:

1. monitor the Lake levels and River flows

2. operate the spill gates to comply with the provisions of the Water Licence for the weir. This includes achieving the scheduled releases and following the rule curve.

3. operate the boat lock to allow passage of boat traffic between the Lake and the River.

The weir is staffed only during the period of control, which currently has been from mid-April to sometime in October or November when the Lake levels are sufficiently high.

We do not foresee the need to increase the number of staff to operate the weir but, to achieve the proposed scheduled releases in years with a low Lake level in late March, it will be necessary to start operation of the modified weir sooner. All simulations with the Cowichan Lake Model for design purposes were based on an "earliest start of control" date of April 1.

Security

The increased head across the weir and the replacement of some of the mechanical components on the boat lock and spill gate structures will affect the operation of the weir. The higher head will put more power in the hands of the operator to cause substantially greater changes in Cowichan River flows than before. In normal circumstances this should not be a problem, but it is conceivable that an emergency could arise where the additional head may be a factor that the operator would need to consider.

With the higher head, and the history of vandalism problems on the weir, the security of the spill gates and boat lock gates will be even more important than it is now. To minimize the likelihood that these devices can be operated or tampered with by unauthorized personnel, continued repair of fencing and installation of additional security measures should be considered for the new weir, especially under maximum head conditions.

We recommend that a trimmed corridor through the brush growing on the island between the timber crib and the spill gate structure be maintained to allow unrestricted visibility of the spill gate structure from the boat lock, where the operator is usually present.

Training

In order to familiarize the former weir operators with the modified weir components, some training will be required during and after the construction period.

3.5 Recreation and Tourism

The proposed weir modifications and release schedule are expected to have both positive and negative impacts on recreation and tourism. None of these impacts are considered to be major. On the positive side, the trout and salmon fisheries should be enhanced by the flow releases, which in turn should benefit residents and visitors interested in fishing. On the negative side, a narrow fringe of the beach area of Cowichan Lake which would be exposed in summer under the current regime, would be underwater after the modifications are in place.

Salmon Fishery

The proposed fall fish releases are intended to stimulate the fall migration of adult Chinook salmon to their spawning grounds. With the ability to control the flows and, in many years, the timing of the runs, a potential increase in tourists and local spectators for this increasingly popular event should be expected.

The enhanced escapement of the salmon is intended to replenish stocks. Although not all directed toward the local communities, this may have a benefit for tourism for southern Vancouver Island in general as a result of an improved sport fishery.

A higher head across the modified weir has the potential to make the weir a more difficult barrier for fish to pass over. The installation of three new fry fishways, one in the vertical slot fishway and one on either end of the concrete sill, are expected to mitigate this impact. The adult fishway would be extended with two new baffles and chambers to accommodate the increased head.

Trout Fishery

The new flow release schedule is also expected to enhance the trout fishery in the Cowichan River. The requirement for increased flows for trout, however, is in the spring. This higher water also allows anglers to access the fish more readily by boat. The combination of these factors is expected to increase the recreational potential of the River for fresh water angling.

Boating

The increased and more predictable flow levels in the Cowichan River may represent a minor benefit to boaters during spring and fall releases. However, the higher head at the boat lock must be controlled to ensure that there is no increased hazard for boat passing through the lock. The main concern here is the potential for rapid filling or draining of the lock when a boat is inside it. Safety measures to deal with this problem are addressed in Section 4.2.

Lakeshore Recreation

Beach activities along the Lake may be affected by the increased lake levels through the summer. The severity of the impact would be related to the areal extent of inundation of what has been exposed beach during the summertime. Residents would be more likely to be affected by this than tourists, because residents will have expectations of a certain size of beach based on experiences in past years.

For example, during July and August the public beach in Gordon Bay Provincial Park would have its width decreased by approximately 5 m, relative to typical beach widths in the 1958 - 1989 period. This corresponds to a 25% decrease in available beach area in mid-June and a 20% decrease in mid-August. The beach at Gordon bay is less steep than most other beach areas around the Lake; however, the percentage decreases for the Gordon Bay beach are likely typical for most natural beaches around the Lake, regardless of slope.

4.0 DESIGN CONCEPTS AND CONSTRUCTION COST ESTIMATES

4.1 Design Procedure

The preliminary design of the structural changes to the weir were developed in a two-stage process. First, a wide range of concepts were considered for each component of the weir. These were compared with one another and, on the basis of design experience, many of the concepts were rejected, leaving only one or two concepts for each component of the weir. The remaining selection was done on the basis of cost, after preliminary design was completed and more reliable cost estimates could be made.

Preliminary design involved the approximate sizing of major new items, and the checking of the adequacy of existing key parts of the weir structures. The purpose of the preliminary design was to identify the major cost items related to the proposed weir modifications. It is important that key assumptions be confirmed and that the design calculations be checked in the final design stage.

Our objective in the design stage was to develop safe and economical designs to raise the weir by 0.57 m, modifying or replacing only those existing items which would no longer meet the acceptable standards because of the new loadings that they would be subjected to. The designs do not include any improvements to the existing weir which are not directly related to the objective of raising the weir crest by 0.5 m, even though some additional improvements may be of interest to Fletcher Challenge.

Description of the Weir

The Cowichan Lake Weir is made up of four different structures. These are listed from the north end southward as follows:

- boat lock
- timber crib weir
- concrete sill
- spill gate structure

Figure 9 shows the layout of the weir and these four components in plan and elevation. Views of these structures appear in Photos 11 to 16. The following sections describe each component and the proposed modifications in detail.

4.2 Boat Lock

Existing Arrangement

The boat lock is a structure with concrete sidewalls, concrete floor and a rectangular steel gate at each end of the lock which slides vertically to open and close (see Figure 10). There are two levels of platforms above the boat lock. The lower deck has the control panels for normal day to day operation, while two upper platforms each support one motor and a pair of hoists. Each gate is lifted by a 5 hp motor which simultaneously drives the two screw hoists, one for each end of the gate. Each screw hoist assembly contains a bevel gear and a large bronze nut which rotates on a threaded shaft when the motor turns, similar to the operation of a rising stem valve.

Proposed Modifications

As shown in Figure 10, we propose that the gate be extended by welding steel plate and required stiffeners to the top of each existing gate; however, an alternative design involving an extension to the bottom of each gate should be investigated during final design. These concepts preserve the existing gate and hoist assembly. The additional height will fit above the existing gate because there is sufficient extra clearance in the structure to accommodate a taller gate.

Adding 0.57 m of head to the upstream side of each gate under maximum head conditions will increase the hydrostatic force on the gates by about 65%. The lower part of the gate will require stiffening to resist the increased bending load. This could be achieved by welding a lateral beam to its downstream face. When the gates are being lifted, the net friction force will also be increased by approximately 65%. The additional load will require replacement of the 5 hp motors with 7.5 hp units.

The capacity of the screw hoists is unknown, as is their condition. These units appear to have been built specially for this application by Dominion Bridge in 1957, and the records pertaining to their design could not be located for this study. We recommend that all critical internal parts of these assemblies be checked for wear and their capacities be determined in the final design stage. The cost estimates presented in Section 4.6 of this report are based on the assumption that the capacities of the screw hoists will be adequate under the new loadings.

Operation

The operator, who is summoned when boats approach the lock, opens the nearest gate. After the boat enters the lock, the first gate is closed and the next gate is opened a small amount to allow the lock to fill or drain as the case may be. After the water levels have equalized, the door is opened wide to allow the boat to exit.

In the winter, both boat lock gates are raised to their highest position, and flow is allowed to pass freely through the lock.

Under maximum head conditions across the existing weir (about 1.0 m) considerable turbulence can occur if the gate is initially opened too much to equalize the levels. There has been at least one incident in the lock where a boat has been overturned and its occupants dumped into the water.

It is imperative that under the proposed maximum head conditions (about 1.6 m) the initial rate of opening be controlled to avoid extreme turbulence and very fast rate of rise when gate starts to open. We recommend that a new safety system be installed as part of the weir modifications that would prevent the fast entry of water into the lock. Such a system could involve instrumentation that would, after the gates have opened a very small amount, disable the motors until the water levels have nearly equalized across the gate.

Construction Considerations

The additional steel for the gate modifications should be prepared in a shop and attached to the gate on site, as it would be very difficult to detach, transport and reinstall the large and heavy gates. The welding might be done from the lower deck if the gates are operable at the time. The work should be done during the winter season, as this would not disrupt boat traffic. The safety system should be tested under maximum head conditions in the spring before the boat lock resumes service.

4.3 Timber Crib

Existing Arrangement

Immediately south of the boat lock there is an overflow section of the weir which rests on the Lake bottom. This structure is made of a series of timber cribs which were floated into position, sunk and filled mostly with rock. Along the upstream face of the cribs, there is a sheet pile wall which was driven into the Lake bed a minimum of 1.52 m. Across the upper part of the structure, six rectangular channels were provided, each with a 0.3 m slot at the downstream end. These were originally designed to act as fishways, but later became plugged with debris and were essentially abandoned when the new vertical slot fishway was built adjacent to the spill gate structure in 1965. A cross section through the existing structure with the proposed modifications appears in Figure 11.

Existing Foundation

The cribs rest on the Lake bed, therefore are not keyed into the foundation, which consists of a weak silt referred to as "bull's liver" by the geotechnical engineers who did the initial investigations. The sheet pile wall on the upstream side is only attached to the cribs at the top, therefore it cannot effectively resist the sliding forces resulting from the hydrostatic force on the weir. The weir upgrade in 1965, which increased the head by 0.33 m, included the placement of a gravel berm with a riprap protection layer on the downstream side of the weir to resist the additional sliding forces.

Concerns about piping failure led the original designers to include a sand filter inside the crib at the base of the sheet pile, with finger drains connecting this filter to the downstream side of the structure. The space between the filter and drains was to be filled with rock and a grout known as Intrusion-Prepakt. The as-built drawings show that the grout infiltrated the drains and plugged them. Of the seven finger drains, four were plugged with grout and two were not installed. A note on the drawing states that "Filter spaces appear to be draining satisfactorily up through filter gravel into rock crib."

Foundation Considerations for Modified Weir

The original weir had a design head of approximately 0.6 m, with some provisions (flashboards) for occasionally raising this to 0.9 m. When the permanent crest was raised by 0.33 m in 1965, designers included the existing berm to resist sliding.

The proposed weir modifications involve increasing the head on the weir by an additional 0.57 m, bringing the total head at maximum normal conditions to about 1.5 m. A preliminary check on the sliding resistance of the existing structure to the proposed head indicated that the weir would fail. To resist the additional hydrostatic force,

the berm on the downstream side would have to be enlarged. Alternative approaches to resisting sliding using a sheet pile wall driven on the downstream side of the cribs with and without batter piles were investigated, but their costs were found to be substantially higher than the cost of a berm.

We recommend that a detailed geotechnical review be conducted at the final design stage to check the berm sizing, and to check the resistance of the proposed structure to a piping failure as a result of the increased head.

Proposed Modifications

We propose that the timber crib structure be modified as follows:

1. Add steel frames and timbers on top of the existing crib to raise the weir crest to an elevation of 162.94 m Geodetic

2. Plug the original fishway slots in the weir with timber walls and fill the space downstream of them with gravel and riprap

3. Place a gravel berm with a riprap protection layer on the downstream side of the timber cribs to the dimensions shown in Figure 11.

A number of alternative concepts were considered before the above scheme was selected. Alternatives included either precast of cast-in-place concrete walls on the timber crib, and a sheet pile wall on the downstream side with or without batter piles to resist sliding. However, the timber alternative was selected because it was less expensive and its expected life was acceptable in view of the apparent remaining life in the timber weir upon which the new works must rest.

The wood on the surface of the timber crib showed signs of age which suggested that it may be nearing the end of its useful life in the

structure. This was communicated to Mr. A. Jezierski of Fletcher Challenge, who advised that they would test the wood in the summer of 1991. We support the need for such testing, and recommend that the wood planks and the 8 x 8 timbers above and below the low water line be tested.

If it is found that the wood should require replacement in the near future, then it would be prudent to combine upgrading the weir with raising its crest in a single construction project. Therefore, we recommend that the DFO explore the possibilities of such a joint project with Fletcher Challenge Canada. As it is not possible to anticipate the results of the wood testing and the subsequent decisions, the design developed and presented herein for the timber crib is based on the assumption that the existing wood will not be replaced before the modifications are built. Our design for an extension to a reconstructed weir would be different from that shown in Figure 11, involving materials and design compatible with the longer life of an upgraded structure.

It is expected that the seepage through the rockfill and the cribs will increase as a result of the higher head. However plugging the old fishways will substantially reduce the cross sectional area available for leakage through the upper part of the structure, therefore we do not expect that the total seepage will be excessive after modifications are complete.

Construction Considerations

The placement of the berm will require access to the downstream side of the crib. We have prepared the cost estimates on the basis of providing a barge to transport the gravel and riprap from the shore to the berm area.

The works on top of the weir would need to be constructed during minimum flow conditions, which will occur in August and September. If the barge operation was to be kept on the downstream side of the weir, then the berm placement may be done during June and/or July.

4.4 Concrete Sill

Existing Arrangement

Between the timber crib and spill gates, there is a small island covered with brush. There is a 0.6 m wide concrete sill buried in the island which acts to maintain the exact weir crest elevation through the island and to prevent formation of a new channel. A section through the sill which shows proposed changes, is presented in Figure 11.

Proposed Modifications

We recommend that the sill be raised using cast-in-place concrete to the new crest elevation of 162.94 m Geodetic as shown in Figure 11. To protect the downstream area from erosion on those occasions when flow may overtop the sill and a low tailwater exists, we propose that riprap be placed at a 5:1 slope as shown on the Figure.

Two fry fishways are to be installed through the sill at the locations shown in Figure 9. These fishways would be provided by the DFO.

Construction Considerations

The formwork and concrete placement should be done during periods of medium to low Lake levels, which are expected to occur in July, August and September. The concrete could be pumped from the left bank. The riprap should be transported to the island by barge at the same time that the riprap is placed in the berm along the crib.

4.5 Spill Gates

Existing Arrangement

The spill gate structure was built in 1965 on what was once a peninsula. When the approach and exit channels for the gates were excavated, the end of the peninsula became the small island where the concrete sill is now located.

The structure has four 4.9 m wide gates which are hinged along the upstream edge and lay flat on the floor of the structure when they are fully open. When they are fully raised, the gates form an angle of approximately 35° with the horizontal. Each gate is raised and lowered by chains which pass over a sprocket on the upper deck and are attached to a counterweight. A cross sectional view through one bay of the spill gate structure appears in Figure 12.

For three of the gates, the lifting force is provided at the sprocket by hand cranks attached to reducers. The gate at the north end is powered by a 1/3 hp electric motor. It is reported that the gates are easy to raise and lower by hand because of the amount of gear reduction provided. However the motor for the north gate has occasionally stalled in a partly open position when closing the gate against high water levels.

Proposed Modifications

Figure 12 indicates the proposed changes to the spill gate structure. It appears feasible to increase the crest elevation of the gates by extending their length by 0.99 m. This would result in the required 0.57 m vertical increase in crest level. A constant thickness gate extension would be welded to the existing steel gates.

To estimate the tension in the lifting chains, a load case analysis was conducted for the existing and proposed weir gates. These analyses showed that the critical load case occurred when the gates were

about half open with the Lake level at FSE and with minimum tailwater conditions. The tension in the chains under this loading almost triples to about 18 kips.

The impacts of the new loads on the rest of the structure are:

1. the counterweight would need to be increased by about 9.5 kips

2. the motor would need to be replaced with a 1.5 hp unit

3. the Babbitt bearings on the sprocket shaft would need to be replaced with bronze or roller bearings in the same size housings

4. the hand crank handles should be lengthened from 0.3 m to 0.45 m

5. the large fishway would require installation of two new baffles and two new sections of fry fishway, to accommodate the higher head across the weir.

We propose that new counterweights be prefabricated, transported to the site, floated into position and installed after removing the existing ones. A more expensive alternative, but probably easier to install, would be to bolt self-supporting steel plates, placed on edge, on top of the existing concrete counterweight.

The existing 1/3 hp motor should be replaced with a 1.5 hp unit. The new motor control should be installed with current overload devices that would stop the motor before overstressing any of the components such as the shafts or chains. The electrical cable to the motor will need to be checked for adequacy during final design, but the cost estimates presented in Section 4.6 include a provision for a new cable.

Operation of Spill Gates

The spill gates will be operated in essentially the same manner as they are now. We propose that one gate remain motorized, and the other three continue to be operated by hand. The motorized gate would operate much the same as it does now, except that after replacement with a larger motor, the gate should not stall in a partly open position under high head as it reportedly has done in the past.

The higher head on the gates will increase the peak loads on the lifting mechanisms by a factor of 2.7, but it is proposed to lengthen the hand crank handles from their present 0.3 m to a new length of 0.45 m. This would reduce the force required at the end of the handle by a factor of 0.75. Therefore, the force required on the end of the handle will be about doubled to approximately 28 lbs. as a result of all the changes.

Construction Considerations

Work on the extension of the steel gates, counterweight replacement and fishway baffle installation could be done during medium and low Lake levels, such as in July, August and September. Work should be done on one gate at a time. It would cause a temporary inconvenience to the operator when the motorized gate is being extended, unless one of the other gates can be connected to the new motor before the north gate is done. The work area can be isolated from the Lake water levels by using the stoplog guides on the upstream side. The downstream stoplog guide would not be usable during or after the installation of the gate extensions because the end of the new gates would interfere with any stoplogs placed in the slots (see Figure 12).

The gate extensions should be fabricated in a shop then welded to the existing gates onsite. There would likely be a need for working plat-

forms to weld the gate extensions into place. The replacement of the counterweights would probably require a large vessel to float them into position.

4.6 Project Cost Estimates

The total project cost estimates are summarized in Table 4 below. A more detailed breakdown of the construction cost estimates is presented in Appendix 4.

Table 4

Summary of Total Project Cost Estimates

Construction Costs:		
Modifications to Boat Lock Structure	$ 41,000.	
Modifications to Timber Crib Structure	93,500.	
Modifications to Concrete Sill	28,700.	
Modifications to Spill Gate Structure	83,000.	
Total Construction Cost:	$246,200.	$246,200.
Final Design and Supervision Costs:		
Geotechnical Design Check	$ 7,000.	
Electrical and Instrumentation Design	3,500.	
Civil and Structural Design	40,000.	
Construction Supervision	15,000.	
Total Design and Supervision Costs	$65,500.	65,500.
Total Project Cost		$311,700.

The total estimated construction cost, in 1991 dollars, is $246,200. With the engineering and construction supervision costs added, the total project cost would be $311,700. The design costs are a high percentage of the total construction costs because this would be a retrofitting project, as opposed to new construction. A detailed design check would be required of all components of the weir and the foundations, especially the sensitive foundation under the crib.

The construction cost estimate includes all the items listed in Appendix 4, or identified as "proposed" in the text of this report and on the figures. Some items which are specifically not included in the estimates are:

1. modifications to or replacement of the screw hoists for the boat lock gates

2. replacement of any existing wood in or on the crib structure

3. design of new fishways or design of modifications to existing ones

4. replacement of any gear reduction units on the spill gate structure

5. replacement of any shafts on the boat lock or spill gate structures

6. survey of identified low elevation lands near the Cowichan Lake shoreline

7. costs associated with mitigating impacts of higher water levels on affected properties.

Contingencies ranging from 15% to 25% were used for the construction cost estimates. These are identified in the detailed cost breakdown in Appendix 4.

5.0 RECOMMENDATIONS

In summary, to achieve the required fish releases we recommend the following:

1. That the following minimum flow release schedule be adopted for the future weir:

Table 5

Recommended Minimum Flow Release Schedule

Period	Flow in m^3/s
April 1 - April 30	21.0
May 1 - June 15	16.5
June 16 - late September	7.0
5-day pulse in late September	21.2
10-day period between pulses	7.0
5-day pulse in early October	21.2 on the first day, reducing in equal steps to 16.0 on the last day
between second pulse and fall floods	9.0

2. That the controlled storage in Cowichan Lake be increased by 36 million cubic metres by raising the weir crest by 0.57 m to an elevation of 162.94 m above Geodetic datum, in order to achieve the release schedule defined above.

3. That the six areas identified on Figure 7 be surveyed to determine how much shore area would be underwater on key dates in the late spring and summer period in a typical year before any decisions on mitigation measures be made.

4. That a detailed geotechnical design check be conducted during the final design stage to check the foundation for resistance to sliding of the weir components, to check the resistance to piping failure, to refine berm size requirements and to estimate seepage through the crib structure.

5. That the wood planks and the 8 x 8 timbers of the timber crib structure above and below the low water line be tested in the summer of 1991 to determine the extent of deterioration and an estimate of their remaining service life.

6. That, if a significant proportion of the wood of the timber crib should require replacement in the near future, the DFO explore the possibilities of a joint project with Fletcher Challenge Canada to upgrade the weir and raise its crest in a single construction project.

7. That a new safety system be installed as part of the modifications to the boat lock that would prevent the fast entry of water into the lock. Such a system could involve instrumentation that would, after the gates have opened a very small amount, disable the motors until the water levels have nearly equalized across the gate.

8. That the development and implementation of additional security measures for the spill gate structure and boat lock structure be considered to more effectively discourage unauthorized operation, tampering or vandalism of these devices, especially during maximum head conditions.

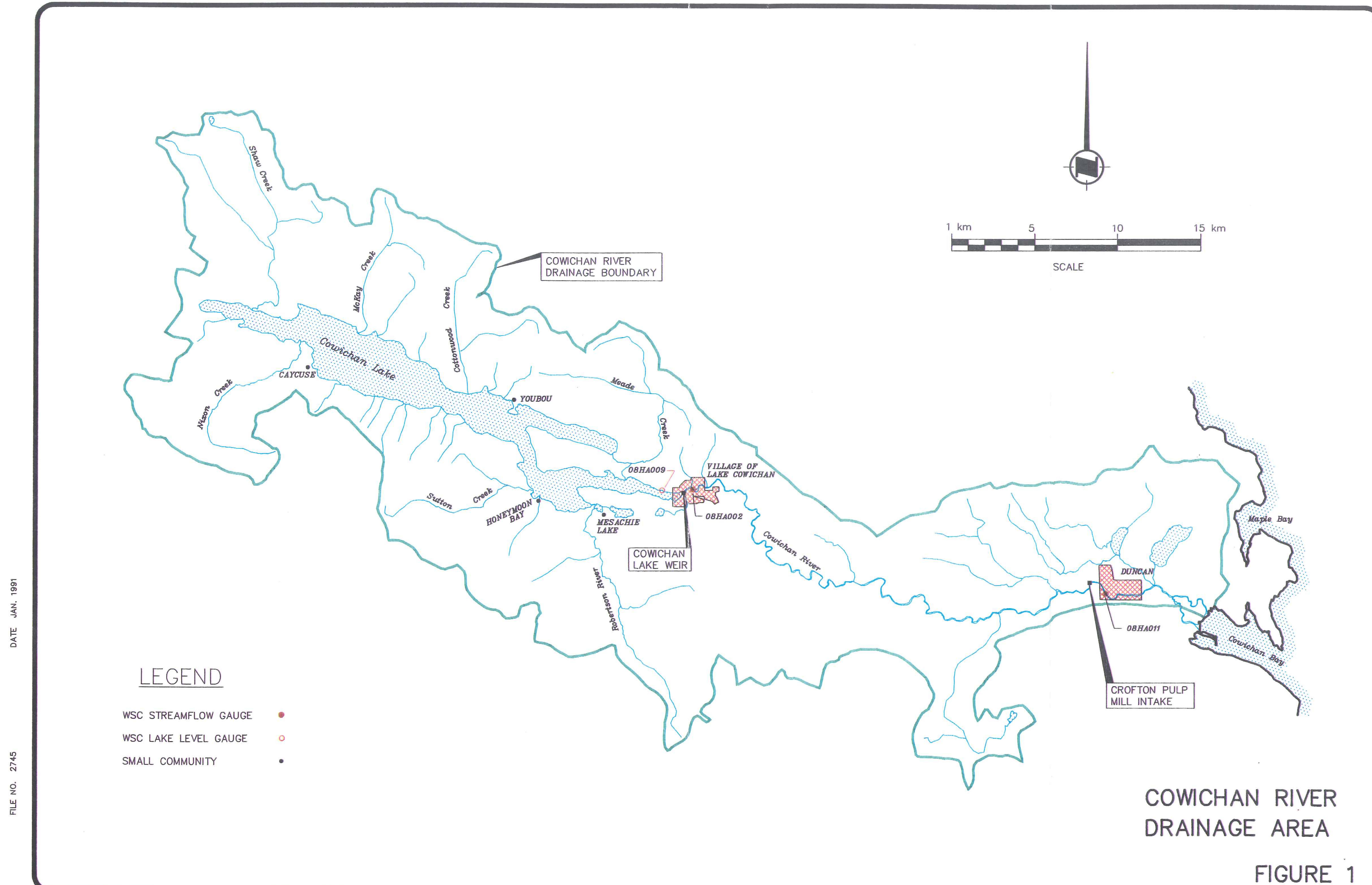
9. That persons residing or having a predictable presence near the River be given advance warning regarding fall fish release pulses.

This report entitled "Final Report on Cowichan Lake Storage Assessment" is respectfully submitted by:

PROFESSIONAL
PROVINCE OF
YAROSLAV SHUMUK
BRITISH COLUMBIA
ENGINEER

KPA ENGINEERING LTD.

Y. Shumuk, P. Eng.

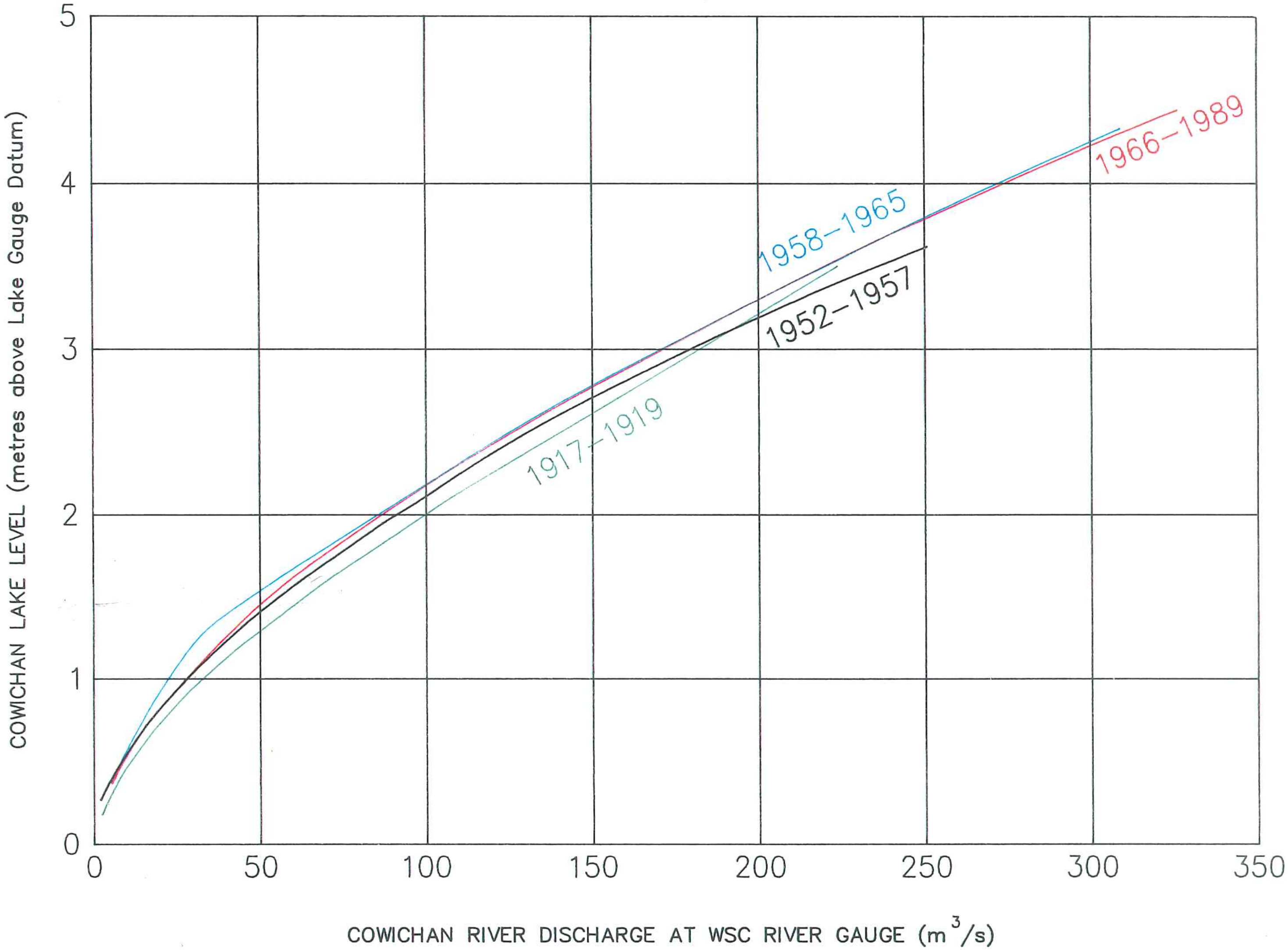


COWICHAN RIVER DRAINAGE AREA

FIGURE 1

KPA ENGINEERING LTD.

FILE NO. 2745 DATE: FEBRUARY 1991



1.43
tog/ weir

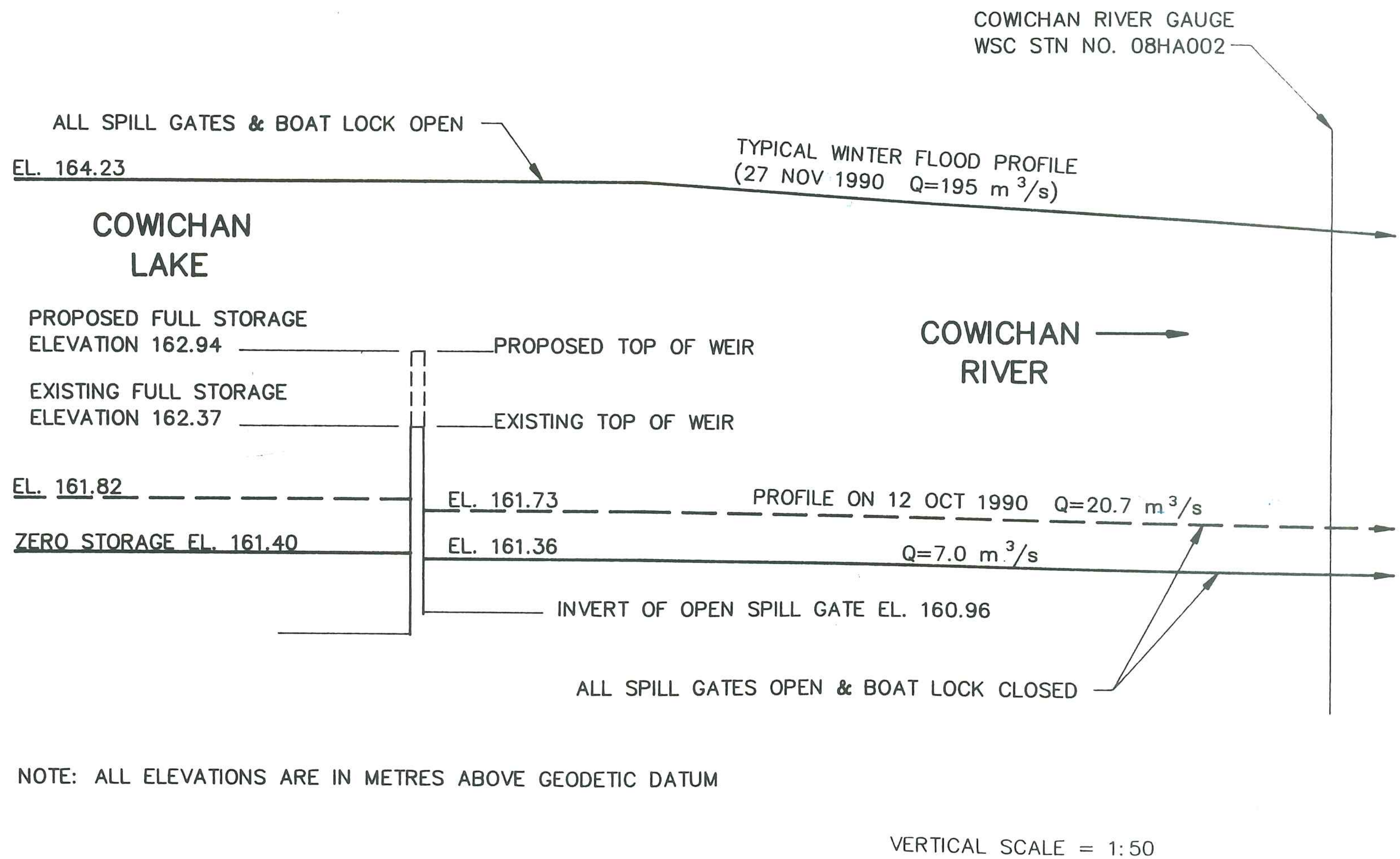
NOTES:
1) DATA PROVIDED BY WATER SURVEY OF CANADA.
2) LAKE GAUGE DATUM = 160.944 METRES ABOVE GEODETIC DATUM.

STAGE–DISCHARGE CURVES AT LAKE OUTLET

FIGURE 2

K P A ENGINEERING LTD.

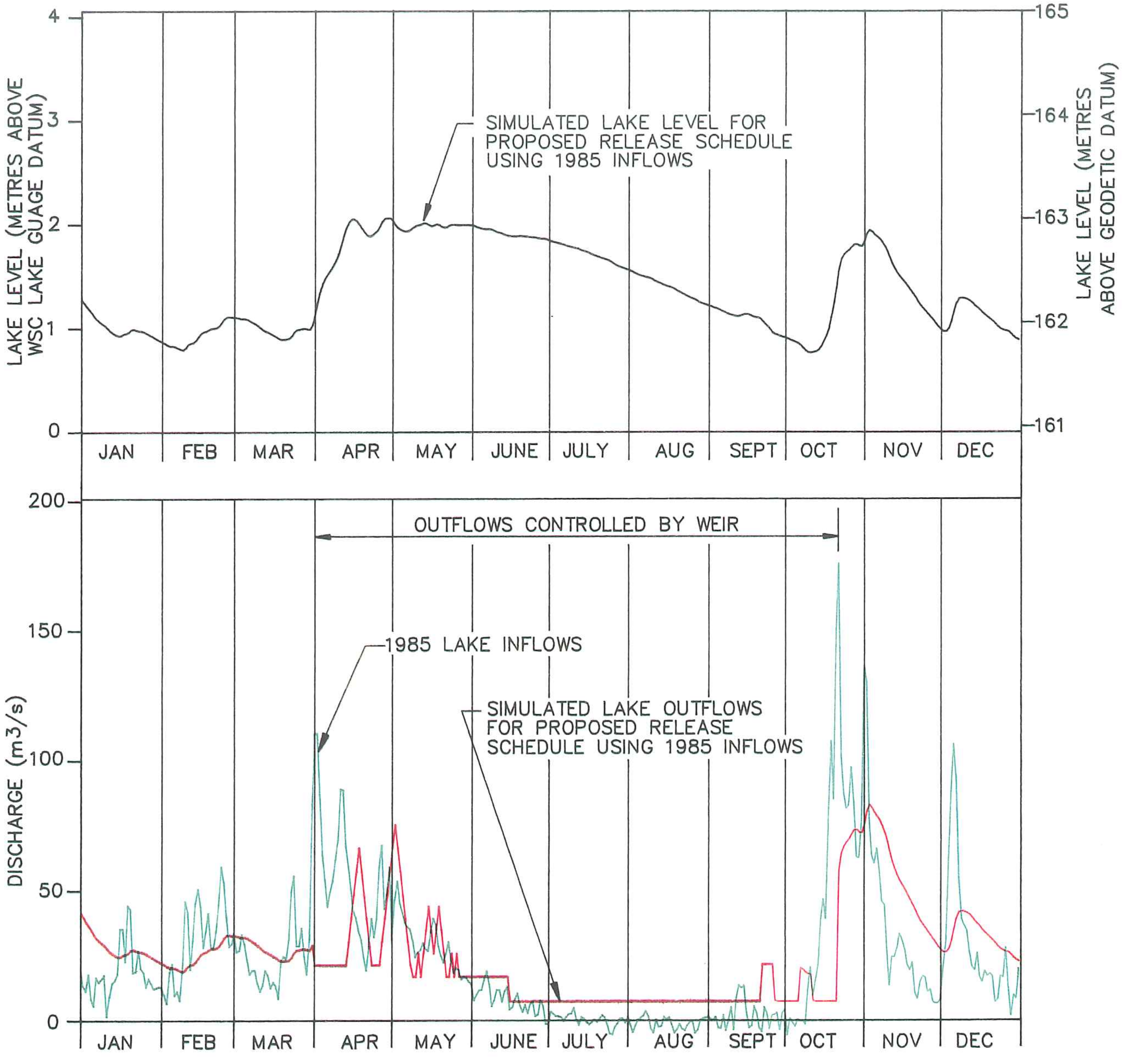
FILE NO. 2745 DATE: FEBRUARY 1991



KPA ENGINEERING LTD.

SCHEMATIC WATER SURFACE PROFILES THROUGH WEIR

FIGURE 3



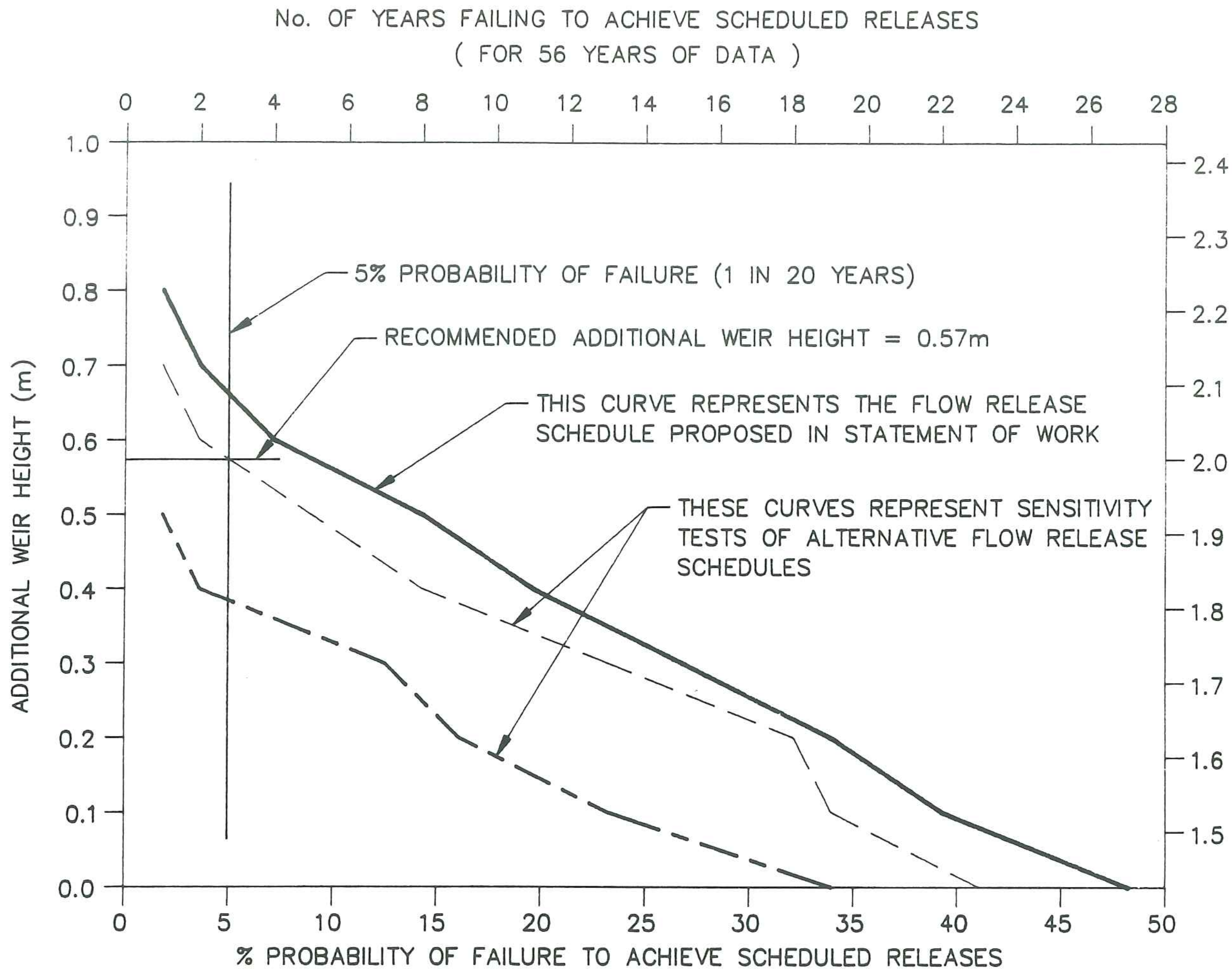
DATE JANUARY 1991

FILE NO. 2745

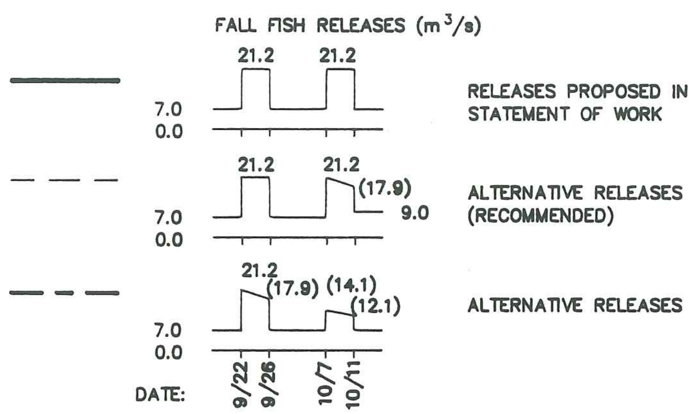
WATER BALANCE MODEL OUTPUT FOR A LOW FLOW YEAR

FIGURE 4

KPA ENGINEERING LTD.



LEGEND



( ) TYPICAL, VALUES WILL VARY FROM YEAR TO YEAR DEPENDING ON INFLOWS

ADDITIONAL WEIR HEIGHT VS ABILITY TO ACHIEVE SCHEDULED RELEASES

FIGURE 5

DATE DECEMBER 1990

FILE NO. 2745

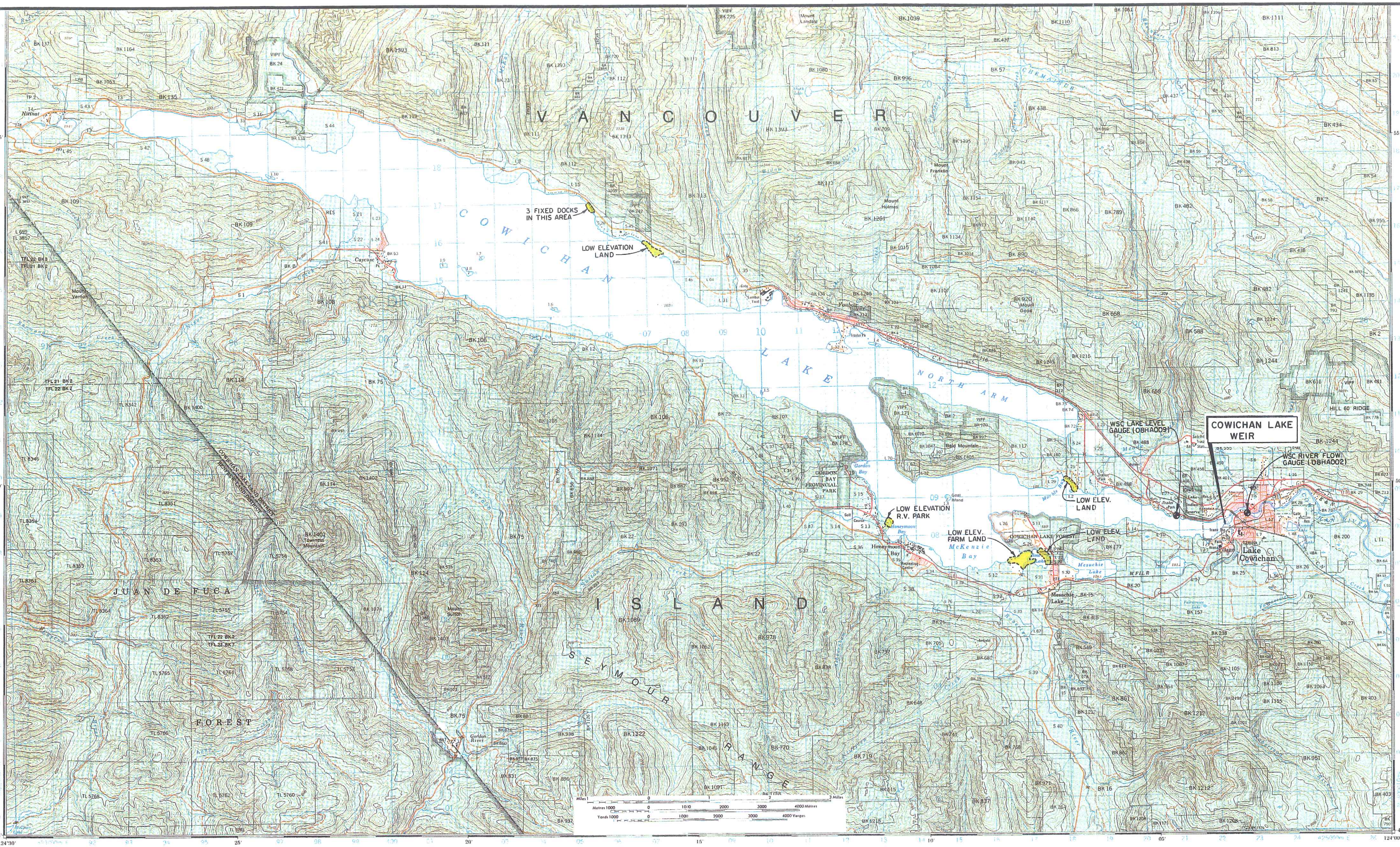
KPA ENGINEERING LTD.

FILE NO. 2745 DATE JANUARY 1991

K P A ENGINEERING LTD.

HISTORICAL LAKE LEVEL SUMMARY AND ASSUMED RULE CURVE

FIGURE 6



MAP OF COWICHAN LAKE

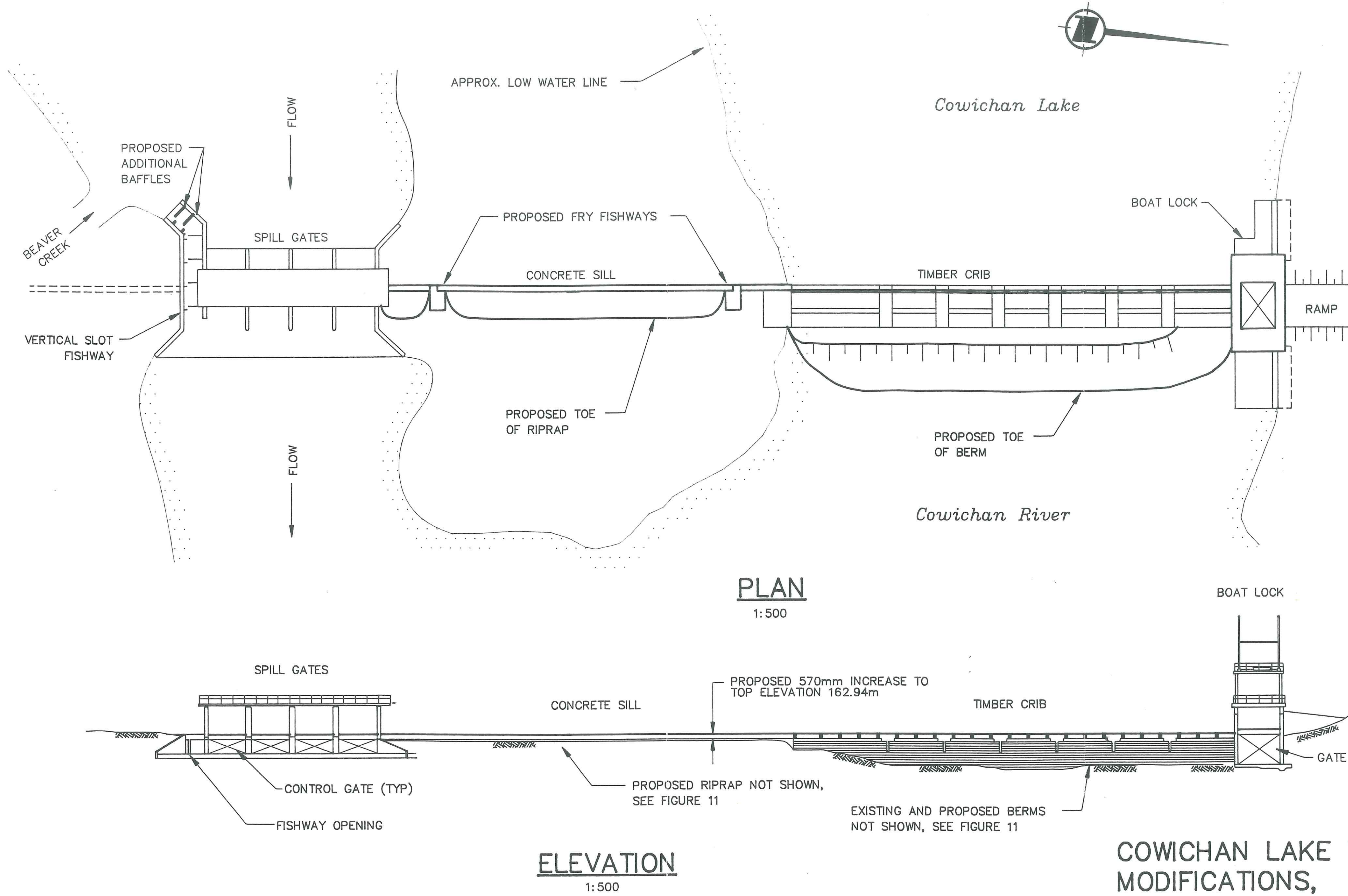
FIGURE 7

KPA ENGINEERING LTD.

FILE NO. 2745 DATE JANUARY 1991

HISTORICAL LAKE OUTFLOW SUMMARY
FIGURE 8

KPA ENGINEERING LTD.



DATE JANUARY 1991

FILE NO. 2745

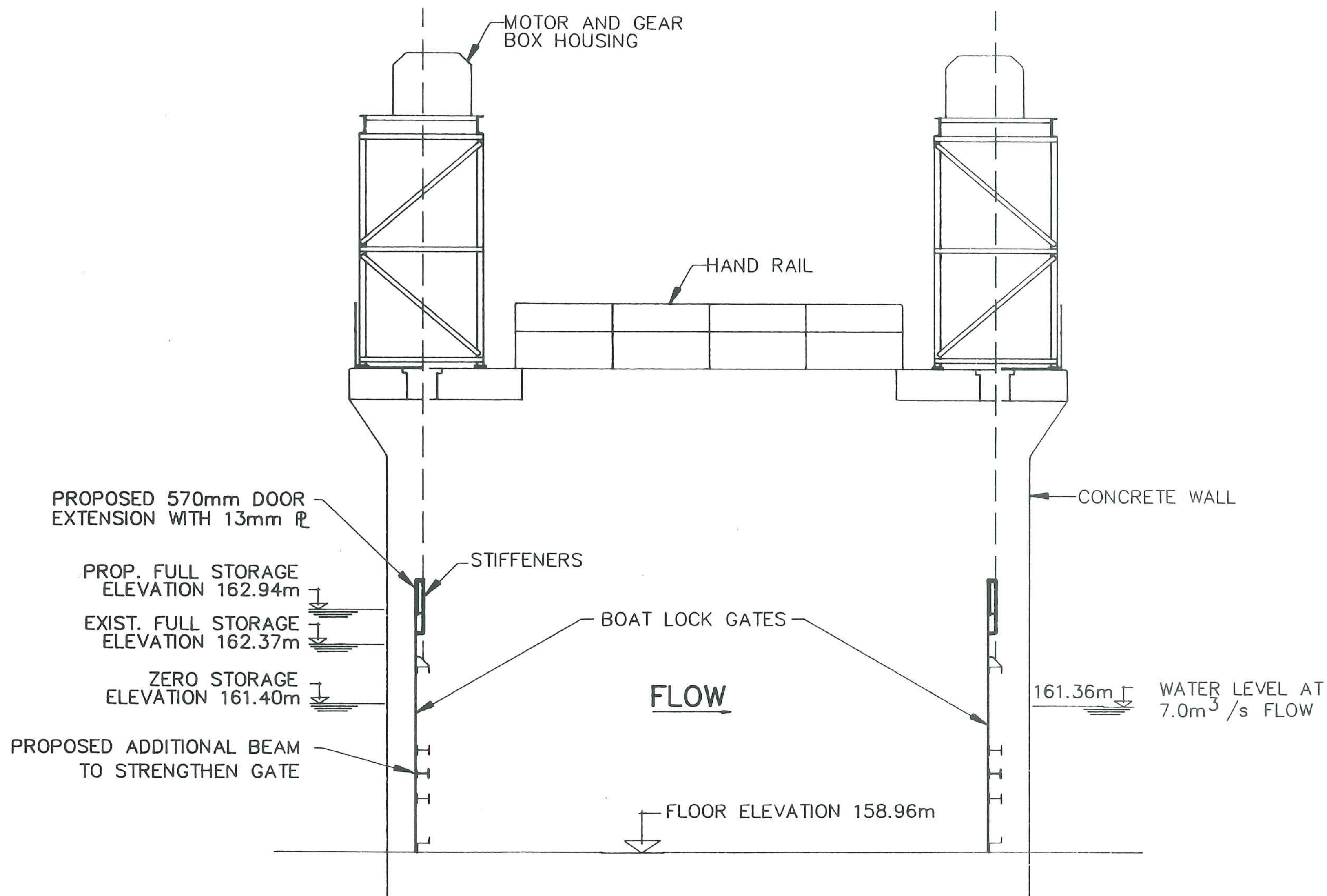
COWICHAN LAKE WEIR MODIFICATIONS, GENERAL ARRANGEMENT

FIGURE 9

KPA ENGINEERING LTD.

FILE NO. 2745 DATE JANUARY 1991

COWICHAN LAKE WEIR MODIFICATIONS, BOAT LOCK STRUCTURE



NOTE:

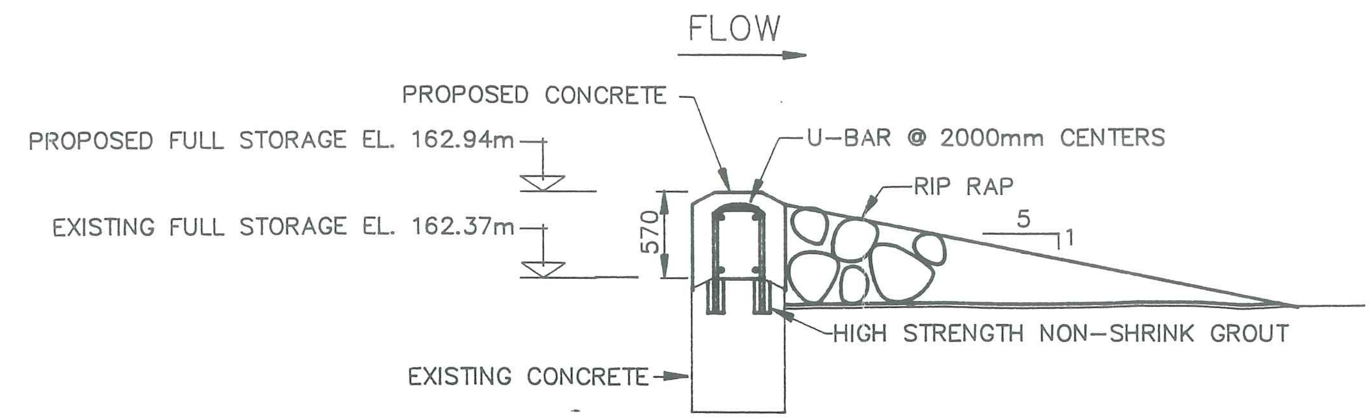
1) PROPOSED MODIFICATIONS INCLUDE REPLACEMENT OF BOTH ELECTRIC MOTORS
2) ELEVATIONS SHOWN ARE RELATIVE TO GEODETIC DATUM

CROSS-SECTION

SCALE 1:100

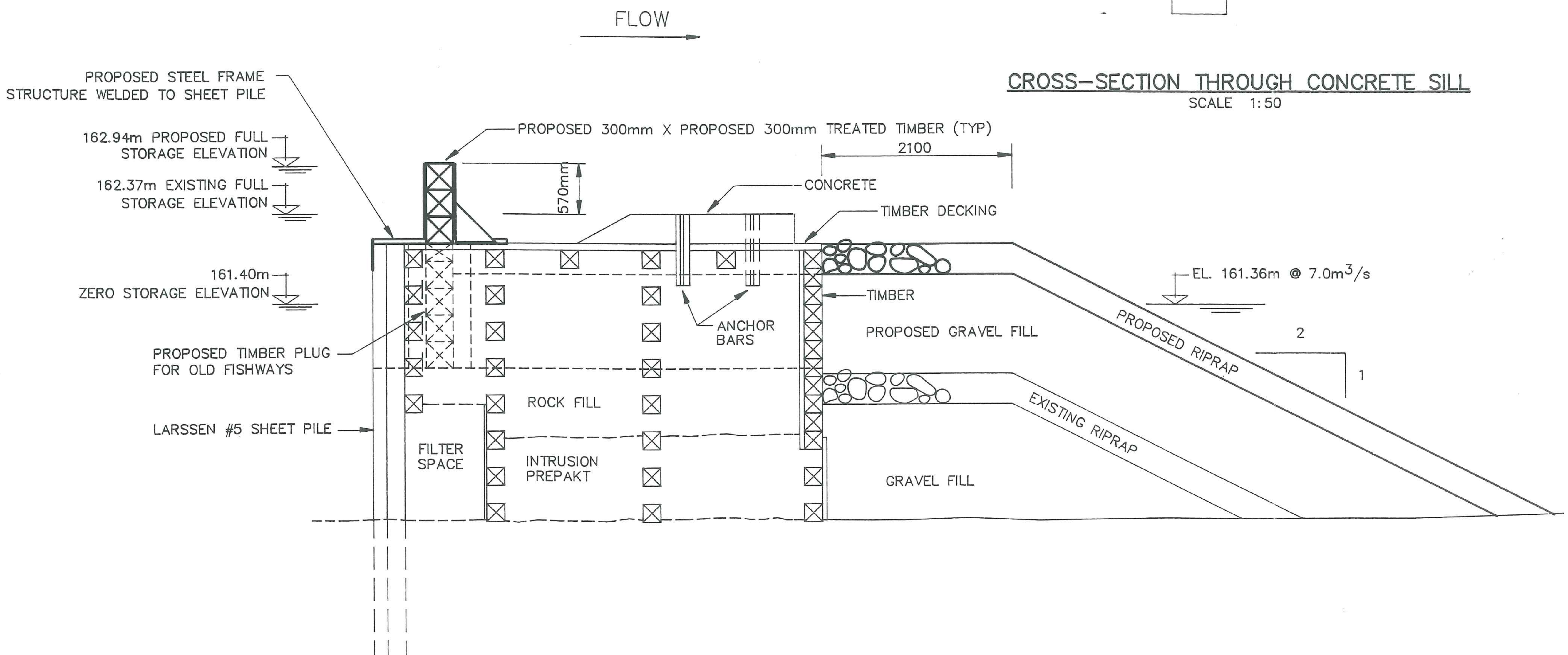
FIGURE 10

K P A ENGINEERING LTD.



CROSS-SECTION THROUGH CONCRETE SILL

SCALE 1:50



CROSS SECTION THROUGH TIMBER CRIB & BERM

SCALE 1:50

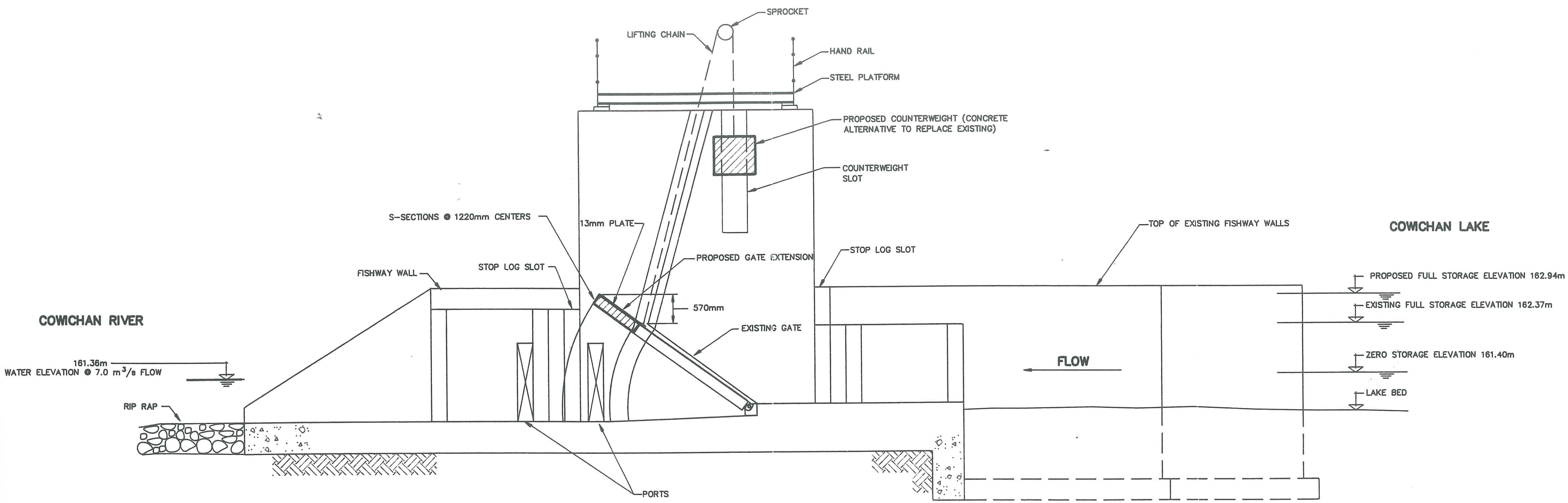
DATE JANUARY 1991

FILE No. 2745

COWICHAN LAKE
WEIR MODIFICATIONS,
TIMBER CRIB & CONCRETE SILL

FIGURE 11

KPA ENGINEERING LTD.



CROSS-SECTION THROUGH ONE BAY OF SPILL GATE STRUCTURE
1:65

NOTE:
1) IN ADDITION TO GATE EXTENSION AND COUNTERWEIGHT REPLACEMENT, MODIFICATIONS INCLUDE REPLACEMENT OF ELECTRIC MOTOR, SPROCKET SHAFT BEARINGS AND HAND CRANK HANDLES.
2) ELEVATIONS SHOWN ARE RELATIVE TO GEODETIC DATUM.

COWICHAN LAKE WEIR MODIFICATIONS,

SPILL GATE STRUCTURE

FIGURE 12

KPA ENGINEERING LTD.

FILE NO. 2745

DATE: JANUARY 1991

Photo 1. *North side residence on Cowichan Lake approximately 0.6 kilometres northwest of Youbou. Lake level : 161.76m*
25 September 1990

Photo 2. *Same location as photo 1. Lake level : 164.23m*
27 November 1990

Photo 3. *Looking north at residence on southeast tip of Marble Bay. Lake level: 161.76m*

25 September 1990

Photo 4. *Same location as Photo 3. Note water levels relative to staircase in center of photo and pick-up truck on right. Lake level : 164.23m*

27 November 1990

Photo 5. *Residence on east side of Bear Lake. Lake level : 161.76m*
25 September 1990

Photo 6. *Same location as Photo 5. Lake level : 164.23m*
27 November 1990

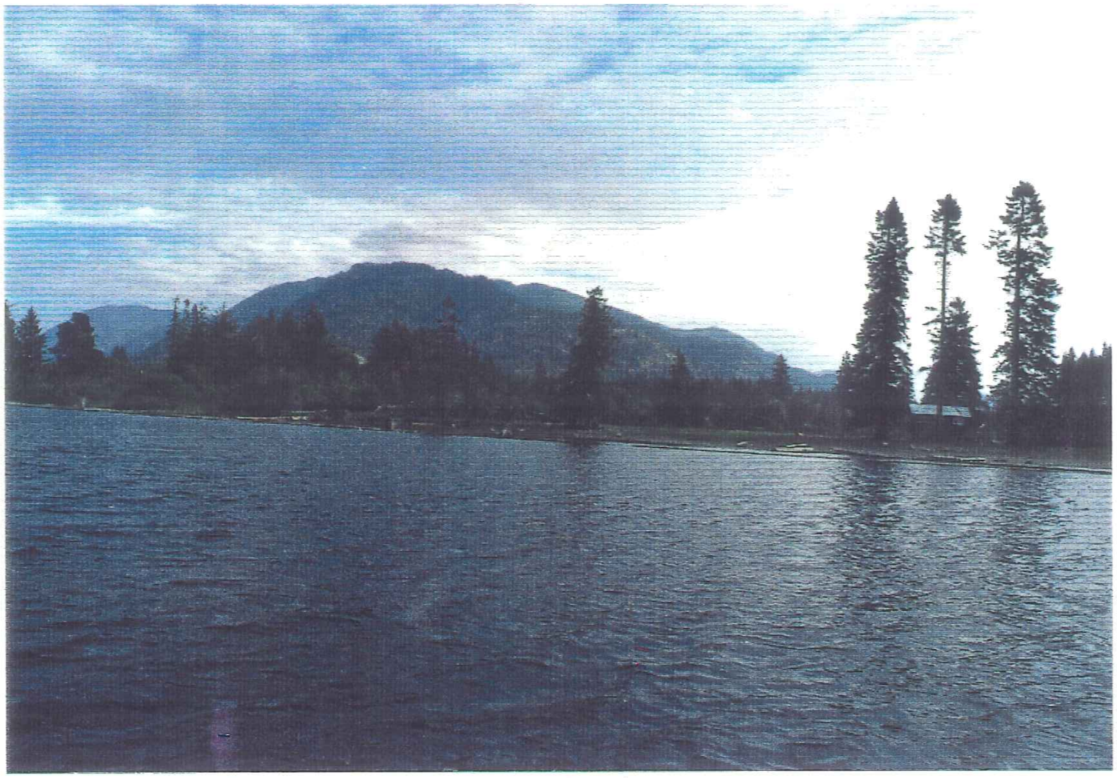


Photo 7. *Farmland at southeast side of McKenzie Bay on south side of Bear Lake. Lake level : 161.76m*

25 September 1990

Photo 8. *Same location as Photo 7. Lake level: 164.23m*

27 November 1990

Photo 9. *East exposure of R.V. Park on westerly tip of Honeymoon Bay.*
Lake level : 161.76m

25 September 1990

Photo 10. *Three fixed docks on north side of Cowichan Lake approximately 0.8 kilometres nothwest of Youbou. Lake level : 161.76m*

25 September 1990

Photo 11. *Looking toward timber crib structure from the boat lock with the Lake level near the existing full elevation.*
18 July 1990

Photo 12. *A similar view at a high Lake level. Note the improved visibility of the spill gate structure when the brush is leafless.*
27 November 1990

Photo 13. *Looking downstream toward boat lock in winter flood conditions. Both gates are raised for the winter season.*

27 November 1990

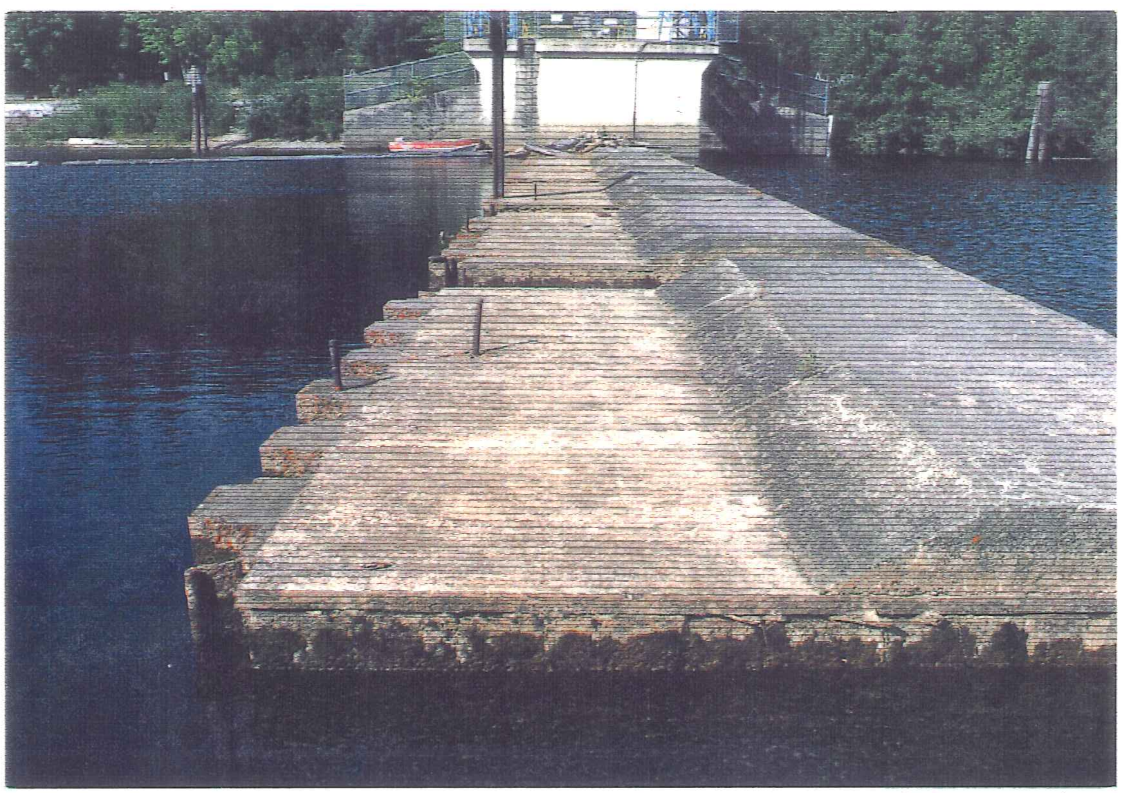


Photo 14. *Looking north toward boat lock with timber crib structure in foreground. Note sheet pile along upstream face and concrete pads used to raise crest in 1965.*

25 September 1990

Photo 15. *Looking upstream toward the spill gate structure with the Lake level near the existing full storage elevation.*

18 July 1990

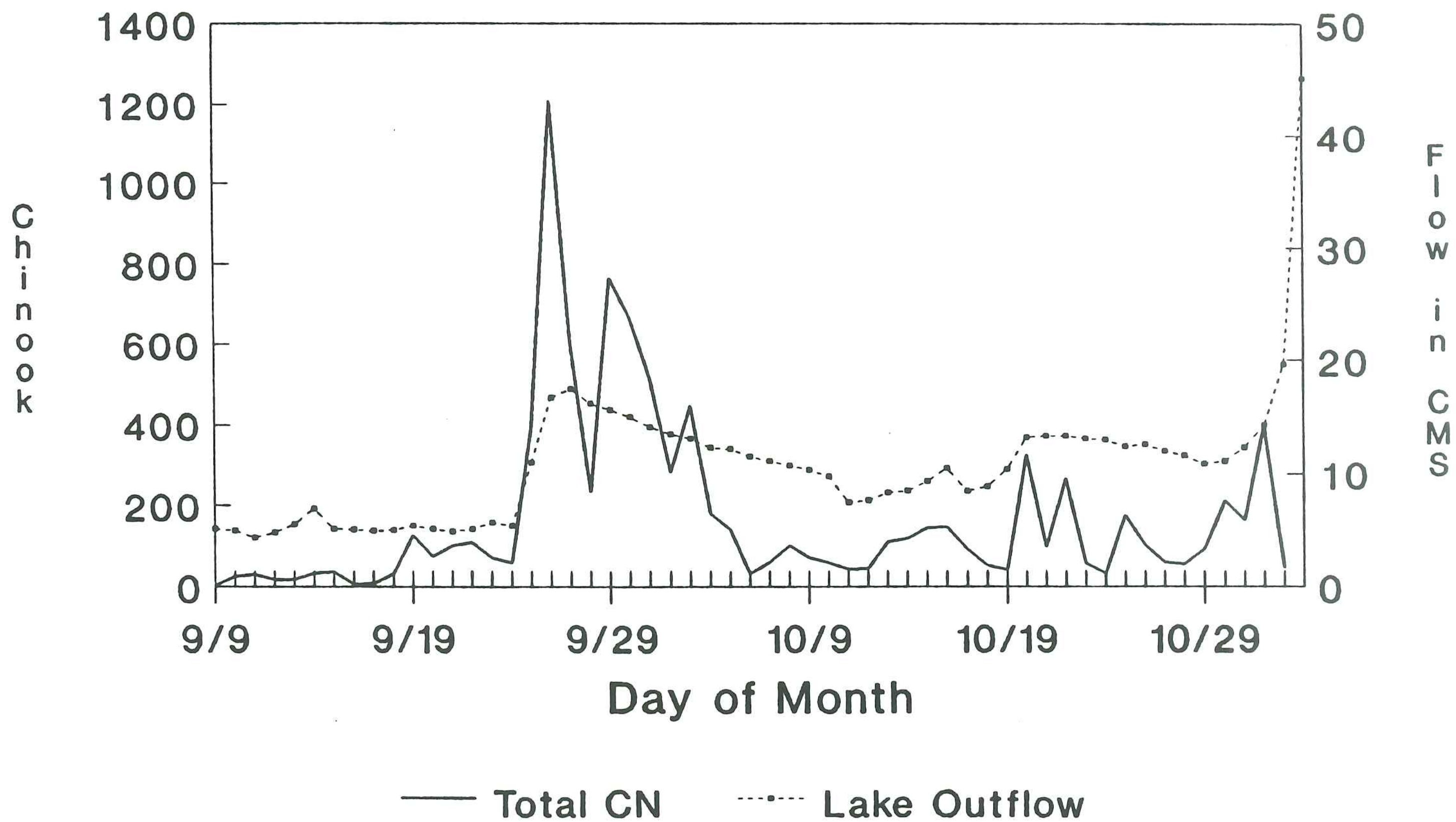
Photo 16. *Looking downstream at two bays of the spill gate structure and the main fishway.*

18 July 1990

APPENDIX 1

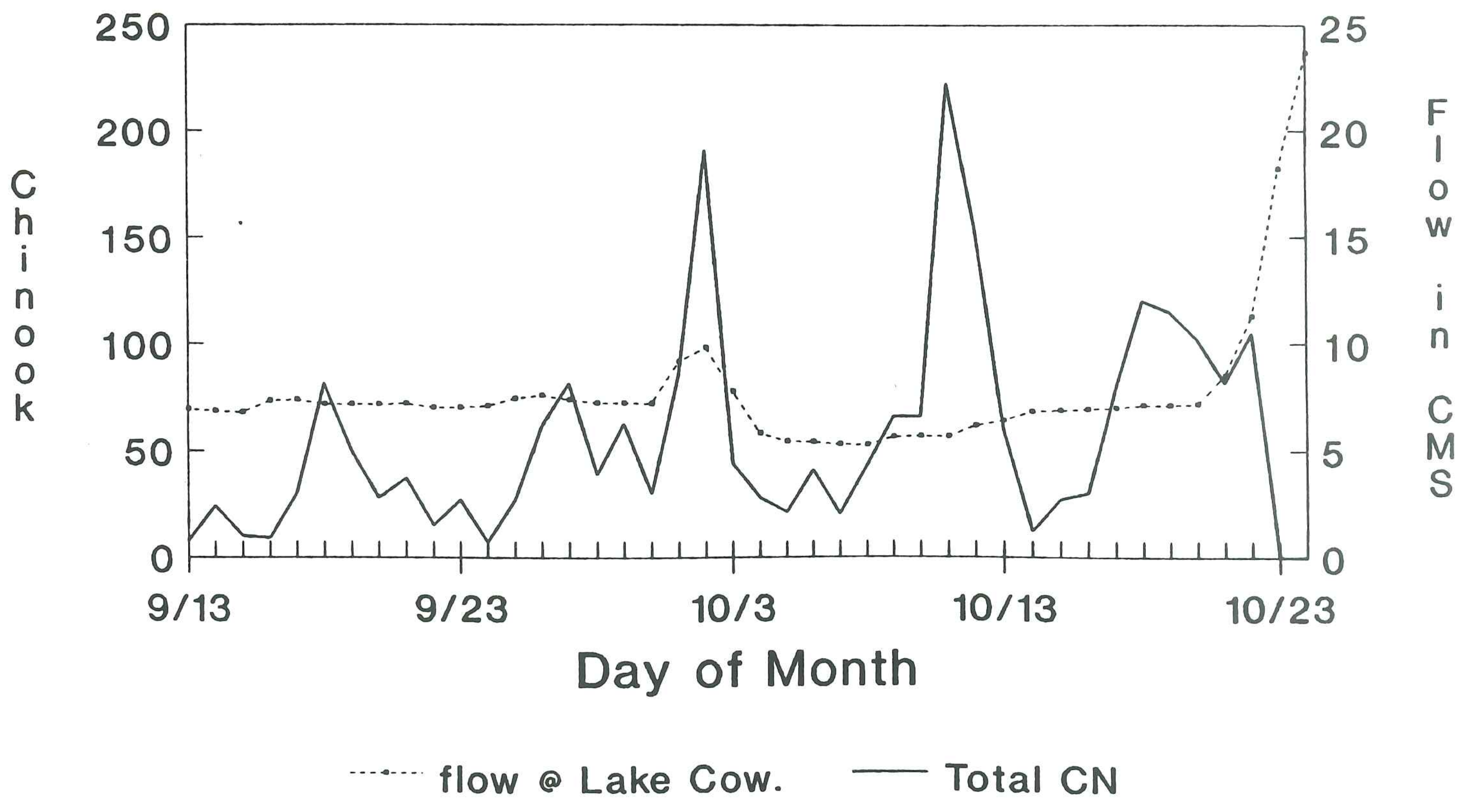
COWICHAN RIVER FLOW RELEASES AND FISH MIGRATION

1988 Cowichan River Daily Chinook Counts
Compared with
Daily Flows at the Cowichan Lake Weir



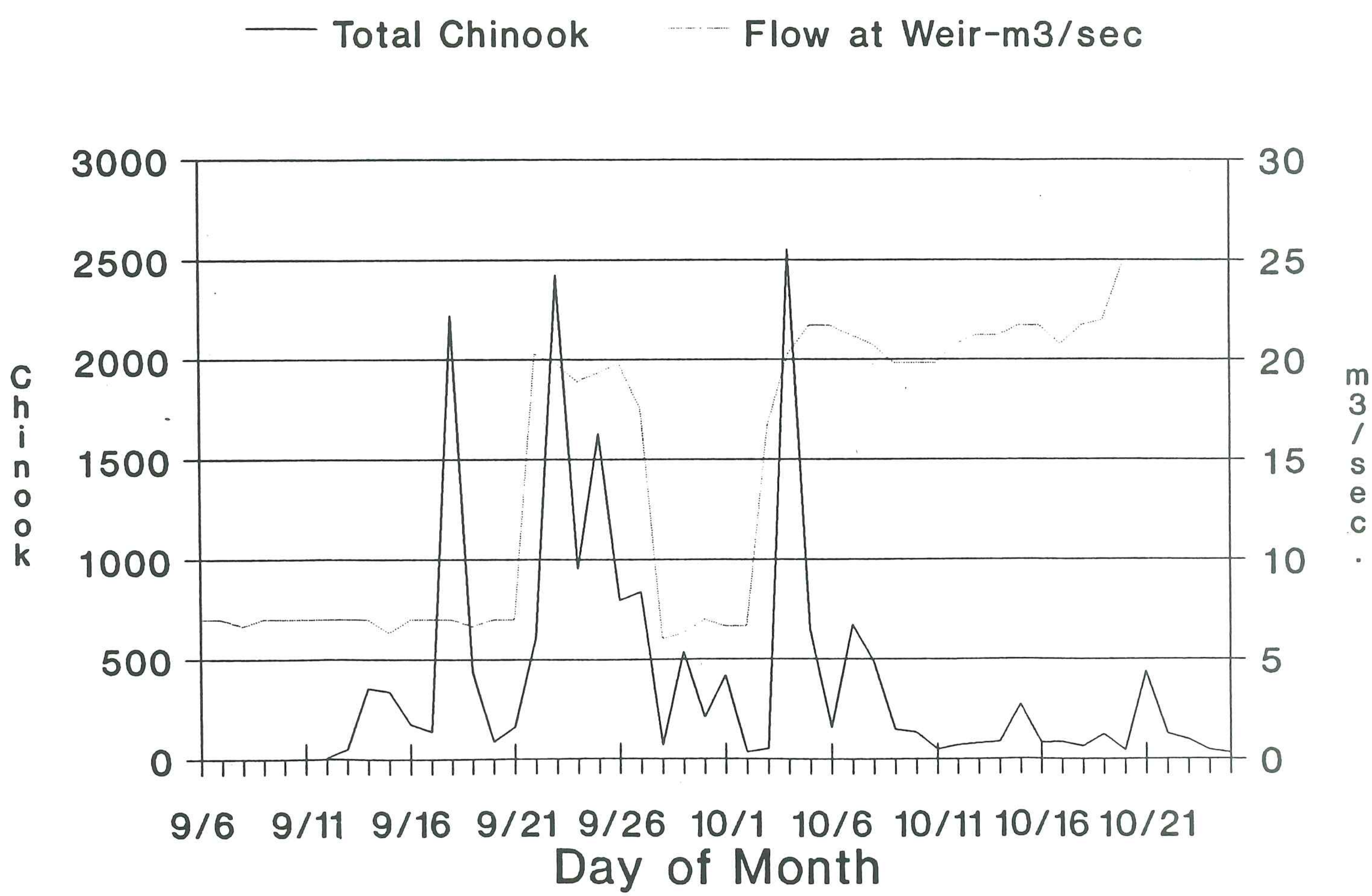
Cowichan Lake weir ceased regulation on
October 16 (end of data).

1989 Cowichan River Daily Chinook Counts
Compared with
Daily Flows at the Cowichan Lake Weir



1990 Cowichan R. Chinook Migration

Compared with River Flow



Discontinued fence operation Oct.25/90.

APPENDIX 2

STATEMENT OF WORK

Joint Federal/Provincial Habitat Development Project - Cowichan L. Storage Assessment.
Statement of Work

Summary:
The Cowichan chinook stocks have been in a serious state of decline for a number of years. Various controversial harvest restrictions were implemented by the Department of Fisheries and Oceans to rebuild the run. As a result of an unusually wet spring in 1988, DFO proposed to test a fall flow release strategy which would assist chinook migration to the spawning grounds. As a result of a prior Min. of Environment, Water Management Br. study, an experimental rule curve was approved by the Regional Water Manager, and the Provincial Fisheries Branch, to maintain full storage in Lake Cowichan (approximately 20 cm. of storage until early July) for release at the Cowichan Lake weir. Pacific Biological Station staff are responsible for the assessment of the Cowichan chinook run as part of the Can./U.S. Fisheries Treaty and was able to assess the affect of the flow release strategy. The chinook escapement was significantly enhanced through the flow release strategy in 1988, the storage was not available in 1989, and is proposed for 1990.

In addition, a high quality river sport fishery exists in the spring for rainbow, cutthroat and brown trout. Enhanced flows during the April 1 - June 15 period will result in an enhanced sport fishery.

In summary, the problem is insufficient storage available to aid chinook migration, and to support the spring sport fishery and enhance salmonid rearing except during unusually wet years. Enhanced flows would also benefit rearing and ensure that **7.0** c.m.s minimum discharge was available from June 15 through late September.

The purpose of this initiative is examine the feasibility of increased storage to provide spring and fall discharges as described in the following **Statement of Work.**

Background:
The Cowichan Lake weir, built in the late 1950's is operated by **Fletcher Challenge Canada Ltd.** to supply approximately 3.11 c.m.s. of water at all times for the Crofton pulp mill. The water is diverted from a pump facility several kilometres above the town of Duncan. The concrete weir, gates, and boat lock at Cowichan Lake are operational when the lake reaches full storage level in the spring. The weir is deactivated when the fall rains rebuild the lake to full storage.

Current Status:
As a result of the success of the 1988 flow release strategy, the Department of Fisheries and Oceans recommended a detailed examination of the feasibility and costs of acquiring more storage in Cowichan Lake. The Water Manager replied indicating that as the adjudicator for provincial water licences, it would be inappropriate for him to undertake the feasibility investigation. As a result, the Department of Fisheries and Oceans and the provincial MOE Fisheries Branch propose to undertake a study of the storage options and review the water budget and historical flow data.

A Fed./Prov. Steering Committee was established May 17, 1990. A contract to undertake a study was recommended and Terms of Reference reviewed. The committee recommended the following **Statement of Work** be prepared to solicit requests for proposals.

1. The contractor will identify the volume of water required to assure the following minimum flows from Cowichan Lake an average of 19 years out of 20:

a) from April 1 to 30: **21** cubic meters per second (cms.);
b) from May 1 to June 15: **16.5** cms.;
c) from June 16 to late September: **7.0** cms;
d) in late September and early October, two (2) pulses of **21.2** cms. for a duration of 5 days each separated by approximately 10 days;
e) in the interval between the pulses, the minimum flow is to be **7.0** cms.;
f) following the pulses, the minimum flow is to be **7.0** cms. until such time as the natural outflow from Cowichan Lake exceeds that minimum.

2. The contractor will determine this volume of water by analyzing historical records of river flows and lake levels as published by Water Survey of Canada, using a water balance model to be developed by the contractor for use on an IBM compatible PC. The model is to be fully documented and installed on the client's computers (2).

3. The contractor will determine the feasibility of storing this volume of water above the present full supply level of Cowichan Lake (162.37 meters Geodetic Survey of Canada datum) and will include the following:
- new weir elevation, structural concepts and costs,
- operational concepts and costs,
- impact on the operation of the existing works,
- impacts on private lands as a result of changes in lake levels.
- impacts on recreation and tourism.

4. The contractor will determine the feasibility of extracting water from Cowichan Lake from below elevation 161.40 meters Geodetic Survey of Canada datum which is presently dead storage and not available for augmenting low flows, and will include the following:
- structural concepts and costs,
- operational concepts and costs,
- impact on the operation of the existing works,
- impacts on private lands as a result of decreases in fall lake levels.
- impacts on recreation and tourism.

5. The contractor will consider only those concepts which have a positive impact on the migration of salmonid species in the river, including all stages from fry to adult. In particular, include any new measures necessary to allow fry to gain access to the lake from the river which is currently part of a habitat restoration project now underway.

It is expected that a contractor will complete a camera ready report before January 15, 1991 or as soon as can be completed. The contractor will also be required to prepare graphic diagrams of the major findings suitable for public hearing presentations as necessary.

The Steering Committee

T. Fields, B.D. Tutty, A. Machel, - DFO
C. Wightman, G. Reid, J. Card - MOE

[Cowichan Chinook Rebuilding Plan - DFO Habitat Development Project]
[Cowichan L. - Increased Storage Project - MOE Habitat Conserv. Fund]

APPENDIX 3

SAMPLES OF OUTPUT FROM THE COMPUTER MODEL

Sample of Summary Printout (2 pages)

COWICHAN LAKE WATER BALANCE MODEL

SUMMARY PRINTOUT

Start year for run 1913
End year for run 1989
Full storage elevation 2.000
Earliest date to stop control OCT 15

Release Schedule

Start date	Stop date	Flow
APR 01	APR 30	21.00
MAY 01	JUN 15	16.50
JUN 16	SEP 21	7.00
SEP 22	SEP 26	21.20
SEP 27	OCT 06	7.00
OCT 07	OCT 07	21.20
OCT 08	OCT 08	20.40
OCT 09	OCT 09	19.60
OCT 10	OCT 10	18.70
OCT 11	OCT 11	17.90

Year	Mean Annual flow	No. of days below min. release flow	First date below min. release flow	Minimum lake level	Minimum outflow	Last date of minimum outflow	Day after last release Lake level
1913	41.40	0	******	0.984	7.00	Oct 06	2.255
1914	53.32	0	******	1.080	7.00	Oct 12	1.907
1915	39.62	1	Oct 11	0.766	7.00	Oct 25	0.766
1916	42.33	0	******	1.081	7.00	Oct 29	1.422
1917	37.64	0	******	0.922	7.00	Oct 03	1.858
1918	52.44	0	******	1.138	7.00	Oct 14	1.376
1919	45.37	0	******	1.105	7.00	Nov 14	1.278
1920	45.73	0	******	0.905	7.00	Sep 12	2.072
1921	49.87	0	******	1.289	7.00	Oct 14	1.768
1941	41.88	0	******	0.898	7.00	Oct 06	2.258
1942	25.45	10	Sep 22	0.630	7.00	Nov 14	0.698
1943	29.50	0	******	0.814	7.00	Oct 26	0.906
1944	28.92	67	Aug 04	0.158	1.27	Sep 11	0.491
1945	43.80	0	******	0.823	7.00	Oct 30	0.872
1946	44.44	0	******	0.767	7.00	Oct 22	1.399
1947	38.18	0	******	0.952	7.00	Oct 15	1.252
1948	46.88	0	******	1.106	7.00	Oct 01	1.978
1949	41.56	0	******	0.697	7.00	Oct 14	1.766
1950	56.87	0	******	1.204	7.00	Oct 06	2.427
1951	45.44	0	******	1.169	7.00	Oct 14	1.505
1952	36.58	0	******	0.948	7.00	Nov 11	1.308
1953	59.24	0	******	1.154	7.00	Oct 01	1.902
1954	57.44	0	******	1.204	7.00	Oct 06	2.077
1955	43.18	0	******	0.878	7.00	Oct 13	1.961
1956	50.27	0	******	1.050	7.00	Oct 14	1.816
1957	34.57	0	******	0.763	7.00	Oct 14	1.755
1958	51.64	0	******	0.859	7.00	Oct 18	1.091
1959	44.02	0	******	1.031	7.00	Oct 14	1.812
1960	44.68	0	******	0.968	7.00	Oct 14	1.472
1961	55.16	0	******	1.033	7.00	Oct 14	1.332
1962	45.97	0	******	0.901	7.00	Oct 05	2.446
1963	51.12	0	******	1.053	7.00	Oct 19	1.069
1964	44.12	0	******	0.950	7.00	Sep 28	1.724
1965	42.17	0	******	1.004	7.00	Oct 14	1.676

Year	Mean Annual flow	No. of days below min. release flow	First date below min. release flow	Minimum lake level	Minimum outflow	Last date of minimum outflow	Day after last release Lake level
1966	52.96	0	******	1.250	7.00	Oct 19	1.406
1967	53.65	0	******	1.193	7.00	Oct 06	2.544
1968	59.65	0	******	1.732	7.00	Oct 04	2.075
1969	43.41	0	******	1.005	7.00	Sep 21	1.970
1970	34.43	0	******	0.811	7.00	Oct 25	0.828
1971	51.45	0	******	1.253	7.00	Oct 14	1.955
1972	46.51	0	******	1.007	7.00	Nov 03	1.406
1973	45.55	0	******	1.118	7.00	Oct 24	1.137
1974	59.00	0	******	1.192	7.00	Nov 10	1.332
1975	55.37	0	******	1.235	7.00	Oct 05	2.152
1976	39.82	0	******	0.937	7.00	Oct 14	1.711
1977	40.21	0	******	1.035	7.00	Oct 24	1.304
1978	28.37	0	******	0.930	7.00	Oct 14	1.954
1979	38.06	0	******	0.786	7.00	Oct 14	1.776
1980	47.42	0	******	1.133	7.00	Oct 30	1.195
1981	51.50	0	******	1.020	7.00	Oct 01	2.180
1982	44.42	0	******	1.183	7.00	Oct 21	1.353
1983	53.66	0	******	1.203	7.00	Oct 21	1.407
1984	49.01	0	******	1.235	7.00	Oct 06	2.708
1985	24.35	5	Oct 07	0.764	7.00	Oct 21	0.768
1986	40.77	0	******	0.815	7.00	Nov 19	0.936
1987	40.81	0	******	0.739	7.00	Nov 24	0.957
1988	39.64	0	******	0.988	7.00	Nov 01	1.186
1989	35.43	0	******	0.845	7.00	Oct 26	0.867

Sample of Single Year Printout (4 pages)

COWICHAN LAKE WATER BALANCE MODEL

YEAR 1985

	JAN			FEB			MAR		
DAY	Inflow	Outflow	Lake level	Inflow	Outflow	Lake level	Inflow	Outflow	Lake level
1	20.0	41.05	1.278	12.9	21.71	0.871	33.5	32.30	1.107
2	13.3	39.34	1.246	10.1	21.14	0.858	26.5	32.15	1.104
3	11.5	37.47	1.210	6.7	20.45	0.841	27.1	31.80	1.096
4	17.8	35.92	1.180	18.7	20.03	0.830	33.2	31.70	1.094
5	8.4	34.40	1.149	21.8	20.04	0.831	29.7	31.68	1.094
6	5.8	32.61	1.113	9.7	19.81	0.825	23.7	31.36	1.087
7	16.7	31.23	1.085	11.3	19.32	0.812	17.9	30.69	1.073
8	14.8	30.25	1.064	7.8	18.80	0.799	19.4	29.93	1.057
9	16.1	29.32	1.044	19.6	18.53	0.792	19.4	29.27	1.043
10	17.5	28.55	1.027	46.0	19.28	0.812	14.5	28.51	1.027
11	1.7	27.39	1.002	41.8	20.61	0.845	11.4	27.56	1.006
12	9.2	26.07	0.973	19.8	21.16	0.858	13.7	26.65	0.986
13	14.5	25.23	0.954	30.8	21.39	0.864	19.5	26.05	0.972
14	15.6	24.63	0.940	45.2	22.31	0.886	17.6	25.60	0.962
15	17.9	24.17	0.930	50.7	23.77	0.920	12.7	24.99	0.948
16	35.3	24.31	0.933	44.0	25.14	0.952	14.9	24.34	0.933
17	35.3	24.95	0.948	28.2	25.79	0.967	13.4	23.75	0.920
18	22.8	25.19	0.953	34.3	26.11	0.974	8.5	23.02	0.903
19	44.3	25.69	0.964	41.3	26.81	0.989	22.0	22.58	0.892
20	43.1	26.76	0.988	28.6	27.30	1.000	24.8	22.62	0.893
21	18.5	27.01	0.994	27.8	27.36	1.002	23.7	22.72	0.896
22	18.9	26.51	0.983	34.5	27.59	1.007	31.2	22.98	0.902
23	27.0	26.29	0.978	44.7	28.32	1.023	49.8	23.99	0.925
24	20.1	26.13	0.974	59.3	29.79	1.054	55.8	25.67	0.964
25	18.7	25.73	0.965	53.4	31.48	1.090	28.9	26.66	0.986
26	13.1	25.15	0.952	40.0	32.46	1.110	28.8	26.80	0.989
27	16.2	24.54	0.938	28.6	32.58	1.112	35.6	27.12	0.996
28	14.4	24.00	0.926	29.6	32.35	1.108	24.8	27.31	1.000
29	12.3	23.39	0.911				18.0	26.95	0.993
30	12.7	22.77	0.897				31.6	26.82	0.990
31	13.2	22.22	0.884				83.5	28.69	1.031

YEAR 1985 cont

	APR			MAY			JUN		
DAY	Inflow	Outflow	Lake level	Inflow	Outflow	Lake level	Inflow	Outflow	Lake level
1	110.4	21.00	1.130	31.0	66.00	2.042	13.9	16.50	1.993
2	110.7	21.00	1.253	46.5	75.00	1.998	7.9	16.50	1.985
3	87.1	21.00	1.361	53.7	66.00	1.970	10.1	16.50	1.974
4	63.6	21.00	1.436	45.2	57.00	1.953	11.7	16.50	1.967
5	54.2	21.00	1.488	41.9	48.00	1.941	11.9	16.50	1.960
6	43.8	21.00	1.526	37.9	39.00	1.936	15.7	16.50	1.957
7	49.5	21.00	1.562	36.2	30.00	1.939	19.1	16.50	1.958
8	53.7	21.00	1.604	35.3	21.00	1.953	13.9	16.50	1.958
9	62.0	21.00	1.655	31.2	16.50	1.973	5.6	16.50	1.949
10	69.9	21.00	1.716	24.5	16.50	1.989	7.9	16.50	1.935
11	89.1	21.00	1.797	26.4	25.50	1.995	11.9	16.50	1.926
12	88.9	21.00	1.891	27.2	16.50	2.003	11.8	16.50	1.920
13	67.3	21.00	1.969	30.0	25.50	2.014	7.3	16.50	1.910
14	59.4	30.00	2.021	27.7	34.50	2.012	11.4	16.50	1.900
15	50.8	39.00	2.050	26.9	43.50	1.996	13.1	16.50	1.894
16	42.6	48.00	2.054	33.9	34.50	1.984	4.3	7.00	1.890
17	39.8	57.00	2.039	39.4	25.50	1.993	5.2	7.00	1.887
18	34.7	66.00	2.005	37.2	34.50	2.005	8.3	7.00	1.887
19	31.2	57.00	1.966	28.8	43.50	1.996	10.6	7.00	1.890
20	24.3	48.00	1.932	25.0	34.50	1.980	6.0	7.00	1.892
21	19.4	39.00	1.902	22.4	25.50	1.971	3.3	7.00	1.889
22	27.9	30.00	1.887	26.1	16.50	1.976	6.0	7.00	1.885
23	39.4	21.00	1.898	30.3	16.50	1.992	2.9	7.00	1.882
24	32.2	21.00	1.919	22.7	25.50	1.999	6.4	7.00	1.879
25	39.3	21.00	1.939	18.3	16.50	1.999	7.3	7.00	1.878
26	59.2	21.00	1.978	20.2	25.50	1.996	1.7	7.00	1.875
27	67.6	30.00	2.030	19.6	16.50	1.995	2.4	7.00	1.868
28	43.0	39.00	2.059	15.9	16.50	1.996	7.9	7.00	1.866
29	48.9	48.00	2.062	16.9	16.50	1.996	5.8	7.00	1.865
30	59.1	57.00	2.064	16.4	16.50	1.996	-1.2	7.00	1.859
31				15.0	16.50	1.995			

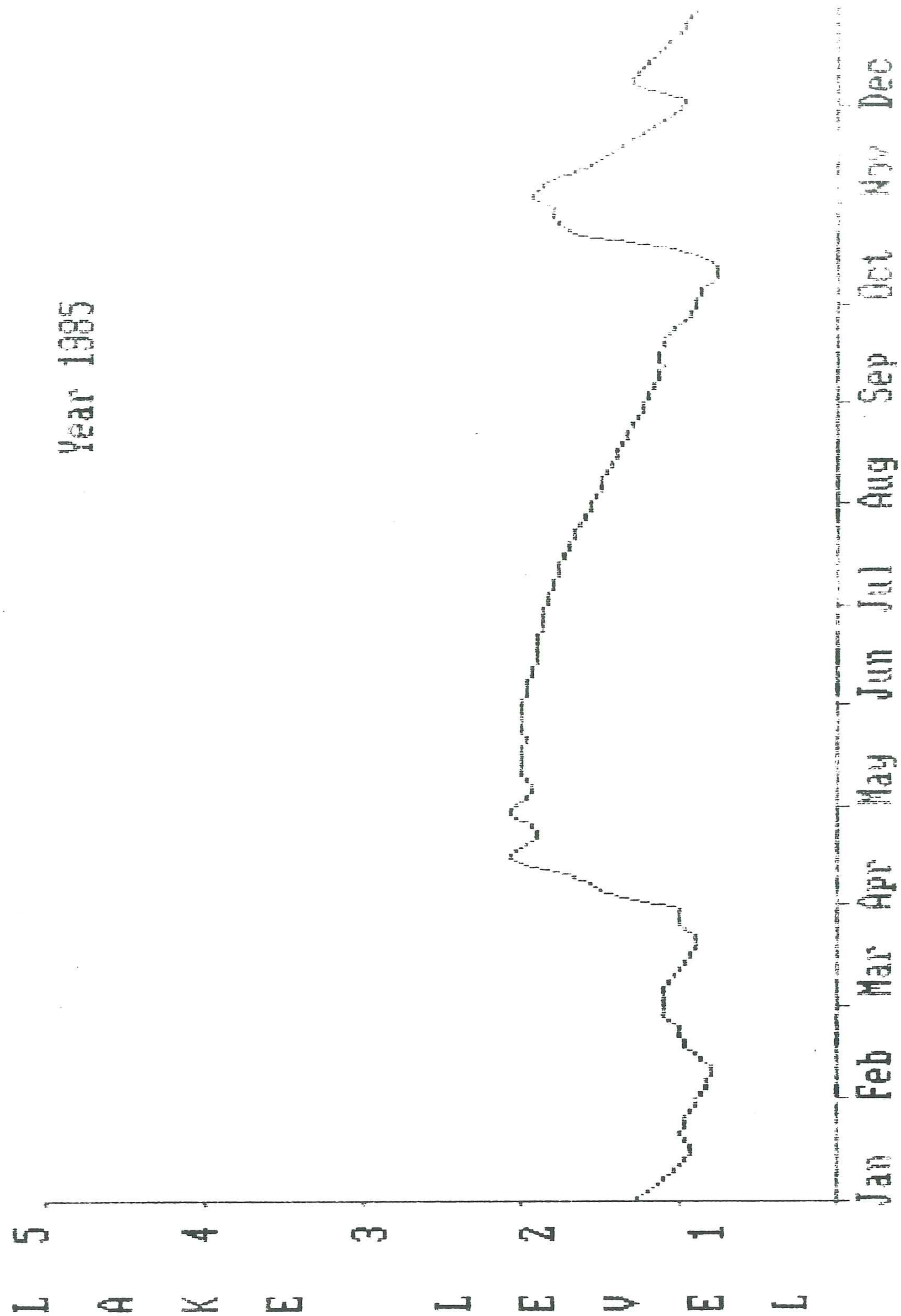
YEAR 1985 cont

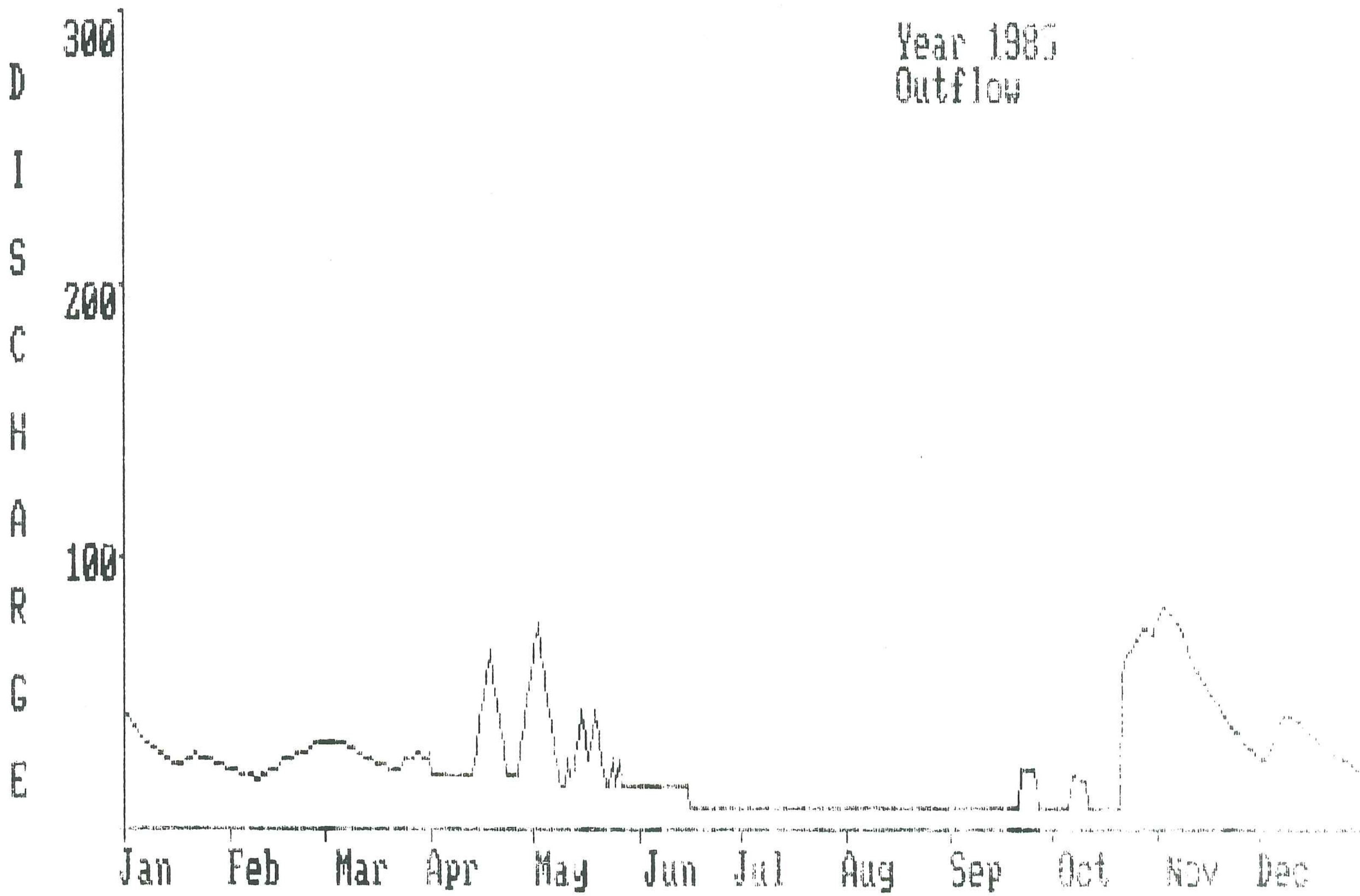
	JUL			AUG			SEP		
DAY	Inflow	Outflow	Lake level	Inflow	Outflow	Lake level	Inflow	Outflow	Lake level
1	-1.5	7.00	1.847	1.4	7.00	1.563	1.3	7.00	1.218
2	3.5	7.00	1.839	-1.5	7.00	1.553	0.7	7.00	1.210
3	2.7	7.00	1.834	-4.5	7.00	1.539	-0.1	7.00	1.200
4	1.7	7.00	1.827	-1.6	7.00	1.525	1.5	7.00	1.192
5	1.7	7.00	1.820	0.4	7.00	1.515	-2.8	7.00	1.181
6	1.4	7.00	1.812	1.0	7.00	1.506	-2.9	7.00	1.168
7	-0.1	7.00	1.804	1.9	7.00	1.499	2.1	7.00	1.157
8	1.4	7.00	1.795	3.7	7.00	1.493	-3.8	7.00	1.147
9	2.5	7.00	1.788	1.6	7.00	1.487	0.2	7.00	1.135
10	2.7	7.00	1.782	-3.2	7.00	1.476	5.0	7.00	1.128
11	4.9	7.00	1.777	-4.6	7.00	1.461	-3.6	7.00	1.120
12	0.6	7.00	1.772	0.4	7.00	1.448	8.8	7.00	1.114
13	-1.7	7.00	1.761	-2.4	7.00	1.437	13.5	7.00	1.119
14	1.3	7.00	1.751	-2.1	7.00	1.425	12.7	7.00	1.128
15	0.8	7.00	1.743	1.4	7.00	1.415	13.3	7.00	1.136
16	-0.7	7.00	1.734	0.5	7.00	1.406	3.1	7.00	1.138
17	-1.5	7.00	1.722	1.2	7.00	1.398	-2.8	7.00	1.128
18	-0.6	7.00	1.711	-1.6	7.00	1.388	-2.0	7.00	1.115
19	0.4	7.00	1.701	-4.7	7.00	1.374	5.3	7.00	1.108
20	-0.5	7.00	1.692	-3.4	7.00	1.359	3.0	7.00	1.104
21	0.8	7.00	1.682	-1.3	7.00	1.346	-2.8	7.00	1.095
22	2.0	7.00	1.675	-3.2	7.00	1.333	-4.3	21.20	1.070
23	1.4	7.00	1.667	-3.8	7.00	1.319	5.1	21.20	1.042
24	-1.6	7.00	1.658	-1.8	7.00	1.305	3.0	21.20	1.018
25	-5.0	7.00	1.643	-0.5	7.00	1.294	-3.6	21.20	0.988
26	-5.3	7.00	1.627	-0.2	7.00	1.284	2.0	21.20	0.958
27	-2.4	7.00	1.612	-4.8	7.00	1.271	2.3	7.00	0.942
28	-1.1	7.00	1.600	-3.6	7.00	1.255	3.1	7.00	0.936
29	0.9	7.00	1.590	0.1	7.00	1.243	-4.0	7.00	0.925
30	0.9	7.00	1.581	0.9	7.00	1.234	3.0	7.00	0.915
31	-0.8	7.00	1.572	1.1	7.00	1.226			

YEAR 1985 cont

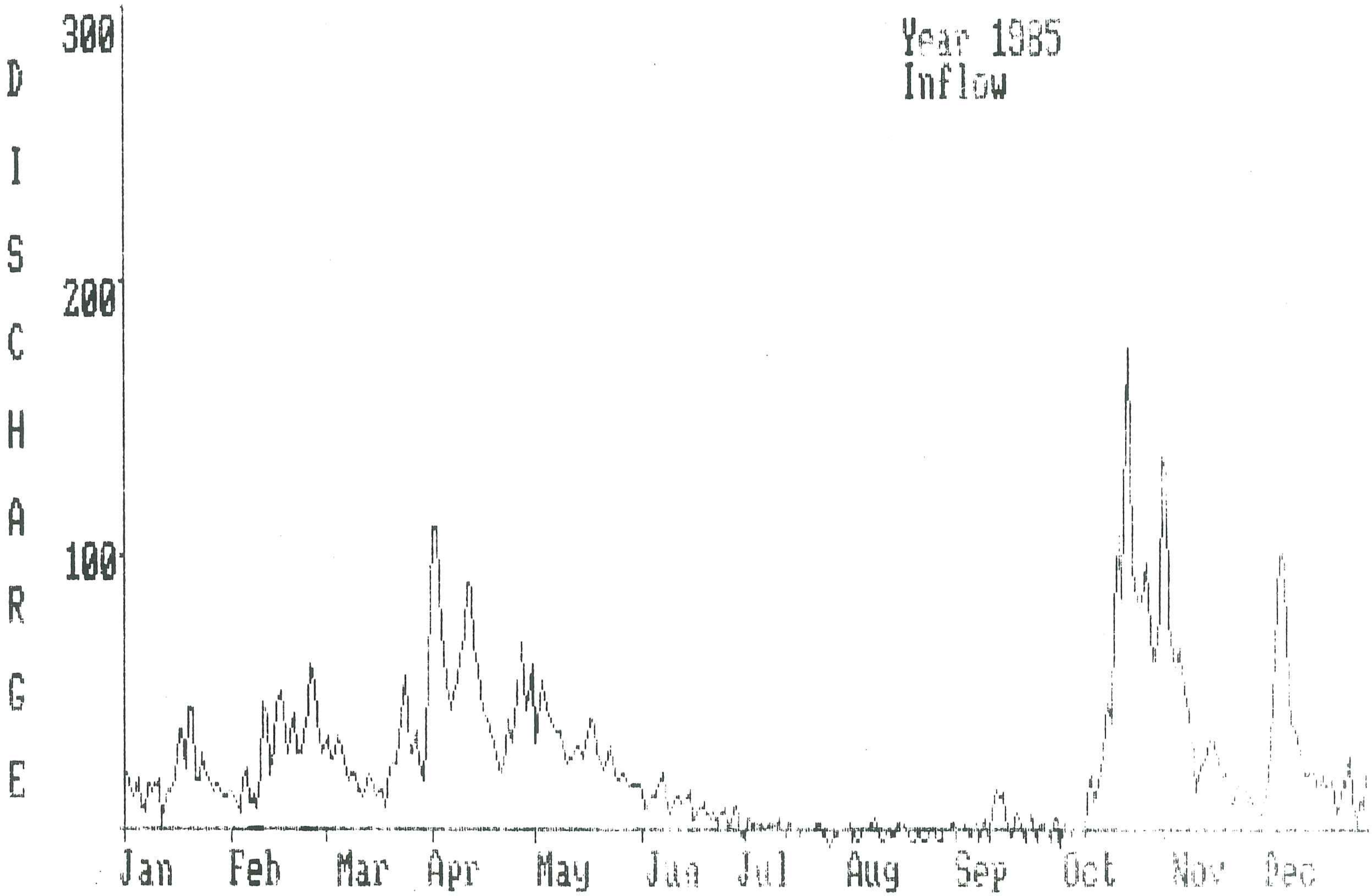
	OCT			NOV			DEC		
DAY	Inflow	Outflow	Lake level	Inflow	Outflow	Lake level	Inflow	Outflow	Lake level
1	4.3	7.00	0.911	137.0	75.12	1.839	8.3	26.62	0.985
2	-6.0	7.00	0.900	131.0	80.45	1.916	21.0	25.91	0.969
3	1.3	7.00	0.887	77.0	82.63	1.947	30.6	25.90	0.969
4	-0.8	7.00	0.878	63.4	81.48	1.931	62.2	27.13	0.997
5	-2.3	7.00	0.866	60.2	79.67	1.905	88.4	30.10	1.061
6	0.5	7.00	0.855	66.6	78.19	1.883	106.8	34.47	1.151
7	-0.2	20.27	0.836	57.7	76.74	1.862	93.6	38.93	1.238
8	-0.1	19.18	0.809	45.5	74.49	1.829	53.9	41.38	1.285
9	-1.5	18.13	0.782	44.6	71.88	1.790	38.9	41.74	1.291
10	12.4	17.48	0.765	26.8	68.73	1.743	36.5	41.45	1.286
11	20.8	17.44	0.764	13.2	64.57	1.679	34.8	41.04	1.278
12	9.2	7.00	0.768	24.8	60.76	1.618	26.4	40.30	1.264
13	15.3	7.00	0.775	24.4	57.81	1.571	20.5	39.12	1.242
14	21.0	7.00	0.790	28.1	55.28	1.529	19.4	37.79	1.216
15	38.9	7.00	0.822	33.5	53.35	1.497	26.2	36.77	1.196
16	47.0	7.00	0.871	31.0	51.70	1.469	16.7	35.73	1.176
17	38.7	7.00	0.921	27.6	49.98	1.439	14.8	34.40	1.149
18	79.2	7.00	0.992	21.4	48.04	1.405	19.2	33.25	1.126
19	108.1	7.00	1.112	19.4	45.98	1.369	17.0	32.27	1.106
20	84.8	7.00	1.235	22.4	44.13	1.335	18.1	31.32	1.086
21	150.6	7.00	1.387	10.4	42.13	1.298	17.1	30.45	1.068
22	176.4	57.66	1.568	8.2	39.80	1.255	6.8	29.29	1.043
23	100.9	64.34	1.675	15.1	37.85	1.217	8.2	27.94	1.014
24	87.0	66.86	1.714	17.1	36.36	1.188	17.4	27.02	0.994
25	81.3	68.34	1.737	16.6	35.05	1.162	16.6	26.42	0.981
26	83.0	69.54	1.755	10.9	33.64	1.134	28.3	26.18	0.975
27	97.8	71.36	1.783	12.1	32.20	1.105	13.0	25.85	0.968
28	83.9	73.07	1.808	7.0	30.75	1.074	1.4	24.76	0.943
29	62.7	73.09	1.809	6.6	29.24	1.042	10.1	23.66	0.918
30	62.4	72.16	1.795	6.8	27.85	1.012	8.3	22.83	0.898
31	77.8	71.98	1.792				19.8	22.34	0.887

Sample of Screen Graphics (3 pages)





Year 1985
Outflow
D I S C H A R G E
300
200
100
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec


Year 1985
Inflow
DISCHARGE
300
200
100
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

APPENDIX 4

CONSTRUCTION COST ESTIMATES

KPA ENGINEERING LTD.

CONSTRUCTION COST ESTIMATE FOR: MODIFICATIONS TO BOAT LOCK STRUCTURE ON COWICHAN LAKE

DATE: FEBRUARY 6, 1991 SHEET: 1

Item	Description	Unit	Quant.	Rate	Amount C$
	MOBILIZATION/DEMOBILIZATION	ls	1	1400.00	1,400.00
	FABRICATION & INSTALLATION OF GATE EXTENSIONS	ea.	2	5500.00	11,000.00
	STRENGTHENING OF GATES	ea.	2	5200.00	10,400.00
	7.5 Hp MOTOR	ea.	2	1500.00	3,000.00
	INSTALLATION OF 7.5 Hp MOTORS	ea.	2	1500.00	3,000.00
	NEW SAFETY INSTRUMENTATION AND MISCELLANEOUS ELECTRICAL	ls	1	4000.00	4,000.00
	SUBTOTAL				$32,800.00
	ALLOW CONTINGENCIES	25%			$8,200.00
	TOTAL ESTIMATED COST				$41,000.00

KPA ENGINEERING LTD.

CONSTRUCTION COST ESTIMATE FOR: MODIFICATIONS TO TIMBER CRIB STRUCTURE ON COWICHAN LAKE

DATE: FEBRUARY 6, 1991 SHEET: 2

Item	Description	Unit	Quant.	Rate	Amount C$
	MOBILIZATION/DEMOBILIZATION	ls	1	5000.00	5,000.00
	MOB/DEMOB OF BARGE	ls	1	20000.00	20,000.00
	INSTALLATION OF GRAVEL AND RIPRAP BERM	hr	72	275.00	19,800.00
	METAL FRAME FABRICATION	ea.	23	200.00	4,600.00
	METAL FRAME DELIVERY AND INSTALLATION	ls	1	3000.00	3,000.00
	12" x 12" TIMBER	ft	700	11.00	7,700.00
	8" x 12" TIMBER	ft	40	8.00	320.00
	3" x 8" TIMBER	ft	120	2.50	300.00
	TREATMENT OF TIMBERS	ft	9000	0.15	1,350.00
	INSTALLATION OF TIMBERS	ls	1	3400.00	3,400.00
	GRAVEL	m^3	390	20.00	7,800.00
	RIPRAP	m^3	145	32.00	4,640.00
	SUBTOTAL				$77,910.00
	ALLOW CONTINGENCIES @		20%		$15,582.00
	TOTAL ESTIMATED COST				$93,492.00

KPA ENGINEERING LTD.

CONSTRUCTION COST ESTIMATE FOR: MODIFICATIONS TO CONCRETE SILL ON COWICHAN LAKE

DATE: FEBRUARY 6, 1991 SHEET: 3

Item	Description	Unit	Quant.	Rate	Amount C$
	MOBILIZATION/DEMOBILIZATION	ls	1	2000.00	2,000.00
	ISLAND BRUSH CLEARING	ls	1	1000.00	1,000.00
	HOLES DRILLED IN CONCRETE	ea.	52	25.00	1,300.00
	FORMWORK	m^2	65	65.00	4,225.00
	REINFORCING STEEL	m	260	1.50	390.00
	HIGH STRENGTH GROUT	ea.	1	35.00	35.00
	PUMPED C.I.P. CONCRETE	m^3	19	350.00	6,650.00
	RIPRAP	m^3	60	32.00	1,920.00
	RIPRAP INSTALLATION	hr	16	212.50	3,400.00
	FRY FISHWAYS IN SILL	ea.	2	2000.00	4,000.00

SUBTOTAL.......................... .... $24,920.00
ALLOW CONTINGENCIES @........... 15% $3,738.00
TOTAL ESTIMATED COST.. $28,658.00

KPA ENGINEERING LTD.

CONSTRUCTION COST ESTIMATE FOR: MODIFICATIONS TO SPILL GATE STRUCTURE ON COWICHAN LAKE

DATE: FEBRUARY 6, 1991 SHEET: 4

Item	Description	Unit	Quant.	Rate	Amount C$
	MOBILIZATION/DEMOBILIZATION	ls	1	2500.00	2,500.00
	GATE EXTENSION FABRICATION	ea.	4	7175.00	28,700.00
	GATE INSTALLATION	ea.	4	3000.00	12,000.00
	BEARINGS	ls	1	1200.00	1,200.00
	BEARINGS INSTALLATION	ls	1	1400.00	1,400.00
	HAND CRANK FABRICATION	ls	1	500.00	500.00
	1.5 Hp GATE MOTOR	ea.	1	1000.00	1,000.00
	1.5 Hp GATE MOTOR INSTALLATION	ea.	1	500.00	500.00
	COUNTERWEIGHT CONCRETE ADDITION	ls	1	4000.00	4,000.00
	COUNTERWEIGHT CONCRETE ADDITION INSTALLATION	ls	1	8000.00	8,000.00
	ELECTRICAL CABLE REPLACEMENT	ft	400	3.50	1,400.00
	FRY FISHWAYS IN MAIN FISHWAY	ea.	2	1500.00	3,000.00
	MAIN FISHWAY MODIFICATIONS (ADDITION OF TWO BAFFLES)	ls	1	5000.00	5,000.00
	SUBTOTAL.				$69,200.00
	ALLOW CONTINGENCIES @. 20%				$13,840.00
	TOTAL ESTIMATED COST.				$83,040.00

KPA ENGINEERING LTD.
consulting engineers
2659 Douglas Street, Victoria, B.C. V8T 4M3
Telephone (604) 388-6676, Fax (604) 388-4014

BY COURIER

MINISTRY OF ENVIRONMENT
RECEIVED
MAY 5 1993
VANCOUVER ISLAND REGION

4 May, 1993

Our File: 3126/E01

B. C. Environment
2569 Kenworth Road
Nanaimo, B. C.
V9T 4P7

Attention: **Bill Hollingshead**
Regional Water Manager

Dear Sirs:

Cowichan Lake Storage Assessment
Effect of Weir Raising on the
Hydraulic Control at the Lake Outlet

As requested by A. Machel, P. Eng., of Fisheries and Oceans Canada, we are forwarding to you the two enclosed copies of our report on the captioned project. If you have any questions regarding this report we would be pleased to try to answer them.

Yours truly,

KPA ENGINEERING LTD.

Y. Shumuk, P. Eng.

YS/bl

Enclosures

Jim Gro
Results as expected should help to convince the property owners

WATER MGR.		
ENG.		
TECH.		
CLERK-STENO		
FILE		

water resources, municipal and structural engineering, mining infrastructure, computer applications.